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ABSTRACT

Based upon Ausubel's theory of meaningful learning, this study focused on the use of concept maps (diagrams that portray relationships among concepts in a given area of study) to help students identify logical relationships between a new concept and concepts already known. Relationships of a learner's prior knowledge and cognitive development to (1) the ability to construct concept maps and (2) the knowledge of environmental concepts as a result of using self-constructed concept maps were investigated. A secondary purpose was to compare three versions of concept mapping. Students (N=114) taking an introductory natural resources course at The Ohio State University were divided into high and low prior knowledge groups based upon pretest results. Within each group, learners were randomly assigned to one of three concept mapping groups: (1) hierarchical-propositional; (2) hierarchical; and (3) propositional. Each student constructed three assigned maps of environmental concepts during the course and completed a posttest on these concepts and an attitude instrument at the end of the course. Findings indicate that prior knowledge, cognitive development, and reasoning ability showed little relationship to students' concept mapping performance. For two groups, prior knowledge explained more variability in posttest scores than did cognitive development. (Author/DC)

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AN APPLICATION OF AUSUBEL'S LEARNING THEORY TO ENVIRONMENTAL EDUCATION: A STUDY OF CONCEPT MAPPING IN A COLLEGE NATURAL RESOURCES MANAGEMENT COURSE

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

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By

Woodward Scott Bousquet, B.S., M.S.

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The Ohio State University

1982

Reading Committee:

Dr. John F. Disinger

Dr. Stanley L. Helgeson

Dr. Robert E. Roth

Dr. Arthur L. White

Approved By

Adviser
School of Natural Resources,
and Faculty of Science
and Mathematics Education

SE 037 877

To my parents

for their love and patient support, and

for the inspiration that their dedication provides.

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VITA

January 5, 1954 . . .	Born--Pittsfield, Massachusetts
1975	B.S., Science Education and Environmental Education, Cornell University, Ithaca, New York
1976	Research Associate, School of Natural Resources, The Ohio State University, Columbus, Ohio
1976	M.S., Natural Resources, The Ohio State University Columbus, Ohio
1977 - 1979	Environmental Interpretor, Assistant Director, McKeever Environmental Learning Center, Sandy Lake, Pennsylvania
1979 - 1980	Teaching Assistant, School of Natural Resources, The Ohio State University, Columbus, Ohio
1980 - 1981	Research Associate, ERIC Clearinghouse for Science, Mathematics, and Environmental Education, Columbus, Ohio
1981 - 1982	Teaching Assistant, Department of Science and Mathematics Education, The Ohio State University, Columbus, Ohio

PUBLICATIONS

"Community-based Environmental Education in Western Pennsylvania." In *Current Issues in Environmental Education - IV*. Columbus, Ohio: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 1978. Co-authored with Thea Teich, *et al*.

"Impact on Environmental Education." In William M. Hammerman (Ed.). *Fifty Years of Resident Outdoor Education: 1930-1980; Its Impact on American Education*. Martinsville, Indiana: American Camping Association, 1980. Co-authored with Robert E. Roth and Diane C. Cantrell.

"Concept Mapping: A Theory-based Strategy for Environmental Education." In Current Issues in Environmental Education and Environmental Studies - Volume VII. Columbus, Ohio: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 1981.

FIELDS OF STUDY

Major Field: Science Education, with a concentration in Environmental Education

Minor Field: Community Sociology

Studies in Science Education
Professors Patricia E. Blosser, Stanley L. Helgeson, Victor J. Mayer, and Arthur L. White

Studies in Environmental Education
Professors John F. Disinger and Robert E. Roth

Studies in Resource Management
Professor John F. Disinger

Studies in Community Sociology
Professor Kent P. Schwirian

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CHAPTER I

INTRODUCTION

Overview of the Study

Ausubel's learning theory emphasizes the central role that concepts and the relationships between concepts play in the learning process. He argues that a person learns an unfamiliar concept by consciously identifying a substantive, meaningful relationship between that new concept and one or more concepts that he or she already understands.

Concept mapping is an instructional technique and learning strategy which attempts to help students learn concepts in the meaningful way described by Ausubel. Essentially a concept map is a diagram, produced by a student or teacher, that indicates relationships among concepts in a given area of study.

The central problem addressed in this research concerned the influence of certain cognitive characteristics of learners upon 1) their ability to construct adequate concept maps, and 2) their knowledge of environmental concepts as a result of using the concept maps they constructed. A secondary purpose was to compare different versions of concept mapping. These analyses were intended to provide insight into the cognitive processes associated with concept learning and concept mapping.

The study involved the 132 students who took Natural Resources 201, Introduction to Natural Resources Management, at The Ohio State University during Autumn Quarter, 1981. Antecedent variables were measured at the beginning of the course. In addition to attending lectures and completing required readings during the quarter, each student made concept maps of three groups of course-related concepts. A posttest on these concepts was administered as part of the regular final examination for the course. Students also filled out an instrument designed to assess their attitudes toward selected aspects of concept mapping.

Presented in this chapter are an outline of the psychological basis of the study and a description of the concept mapping strategy. These background discussions are followed by a description of the research problems, subproblems, and hypotheses.

Psychological Basis for the Study

The theory of learning developed by Ausubel (Ausubel, 1963; Ausubel, Novak and Hanesian, 1978) stresses the importance of concepts in learning. Ausubel states in the epigraph to his text (1978, p. iv):

> If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.

The most important aspects of "what the learner already knows" are the particular concepts that the learner possesses in cognitive structure. Through subsumption -- the incorporation by a learner of new knowledge into a relevant, more inclusive concept which is already known -- a person learns unfamiliar concepts in a non-arbitrary way.

Subsumption lies at the heart of what Ausubel terms meaningful learning; his theory is generally referred to as the theory of meaningful learning. The opposite of meaningful learning is rote learning, in which a learner makes arbitrary associations between the learning material and his or her existing store of concepts. Meaningful learning has several advantages. First, concepts that are learned meaningfully can expand a person's knowledge of related concepts. Since meaningful learning involves the intentional construction of substantive, logical links between new concepts and pre-existing knowledge, information learned meaningfully will be retained longer (Ausubel, 1960). Finally, these concepts can later serve as subsumers -- mental anchors -- for learning additional related concepts.

Ausubel (1979) argues that instruction should emphasize the most general and inclusive concepts of an area of study. The nine unifying themes of biology formulated by the Biological Sciences Curriculum Study (Schwab, 1963) and the five conceptual strands used by the National Park Service (National Park Foundation, 1975) in their National Environmental Education Development (NEED) project provide good examples of inclusive concepts. Such broad concepts are powerful because they can have direct relevance to subsequent learning experiences, they provide the broadest subsumers for new but related subject matter, and they assist learners "in integrating the component elements of new knowledge both with each other and with existing knowledge" (Ausubel, 1979, p. 182).

In addition, Ausubel points out that each student's store of concepts is unique. Therefore, each person will construct different concept links while involved in the same learning task. In order to enable each person to accomplish this, instruction must allow learners to reformulate the material in ways that are meaningful to them.

Although the theory of meaningful learning has numerous additional implications for educational practice, those discussed here are the most relevant to the concept mapping strategy investigated in this study.

Concept Mapping

From the preceeding discussion, it follows that concept learning activities based upon Ausubel's theory of meaningful learning should involve learners in 1) identifying concepts in the material to be learned, 2) determining which of these concepts are the more general and inclusive, 3) meaningfully linking these concepts to each other, and 4) meaningfully relating these concepts to concepts they already know.

An instructional technique and learning strategy that has been designed according to these theory-based criteria is the concept map. This approach was developed and is being assessed by Joseph Novak and his research group at Cornell University (Stewart, Van Kirk and Rowell, 1979; Novak, 1981; Novak and staff, 1981). In essence, a concept map is a diagram that indicates relationships among concepts in a discipline, a part of a discipline, or an interdisciplinary area of study. Maps depict not only concepts themselves but also propositions, which describe meaningful relationships between pairs of concepts.

A teacher, a student, or a group of students can construct a concept map. Figure 1 shows a concept map of energy flow in an ecosystem. The most inclusive concept, ecosystem, appears at the top of the map. As one progresses down the map, the concepts become less inclusive and more specific. Unlike an outline, a concept map is two dimensional. This characteristic allows the portrayal of the complex connections that exist among concepts. For example in Figure 1 the concept "physical environment" is linked vertically to the more general concept, ecosystem, above it and to the more specific concept, sunlight, below it. Furthermore, the map includes the concepts producer, herbivore, carnivore, and decomposer which lie at the same hierarchical level.

Since each person possesses a unique organization of concepts and propositions in his or her cognitive structure, a concept map that is meaningful to its maker may not be the most meaningful arrangement to another person. There is thus no single "correct" concept map; the best maps are those that are most meaningful to persons who construct or read them. However, each map should also meet the following criteria (Bousquet, 1981, p. 76):

1. Concepts are arranged in a hierarchy; i.e., the map starts with the most general concepts at the top and proceeds downward to the most specific concepts or examples;

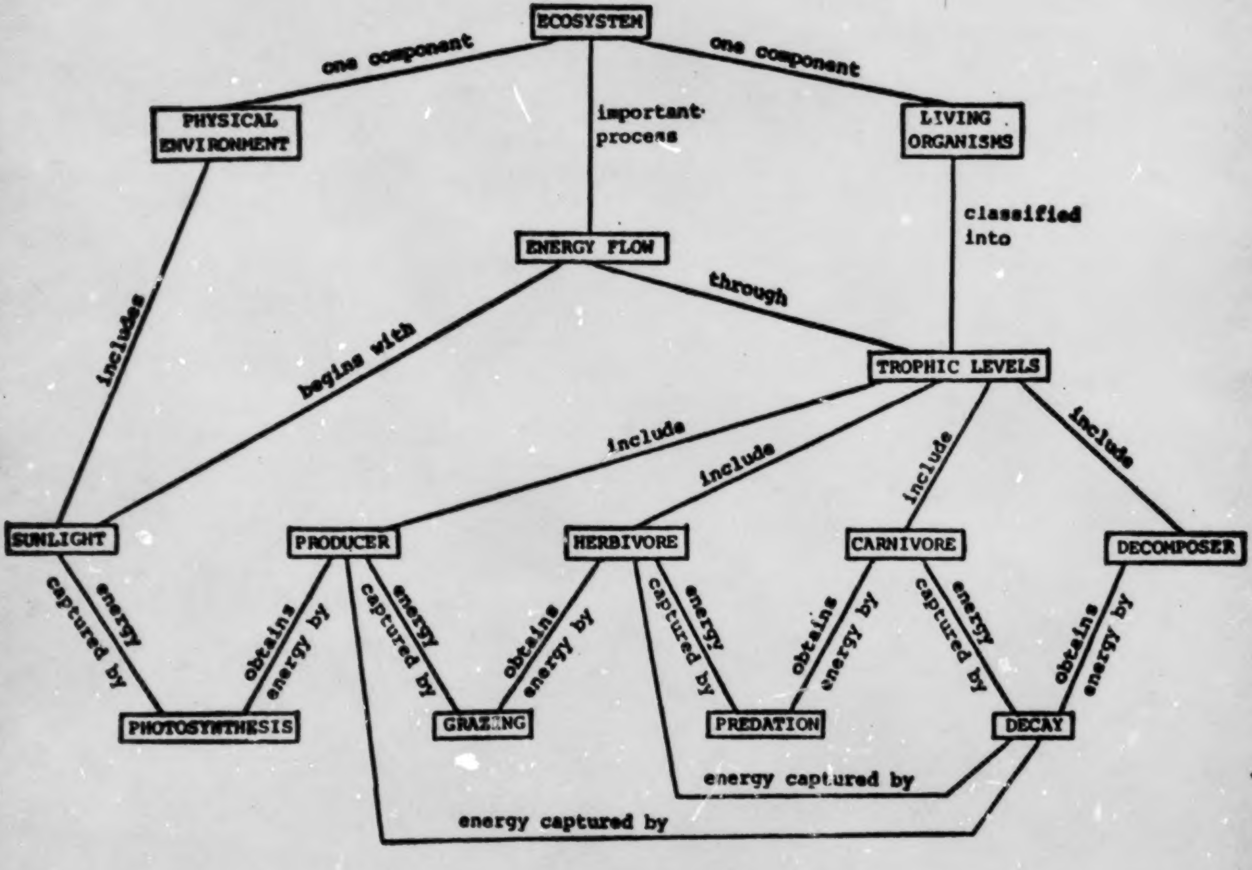

ECOSYSTEM
one component
one component
PHYSICAL ENVIRONMENT
important process
LIVING ORGANISMS
classified into
ENERGY FLOW
includes
begins with
through
TROPHIC LEVELS
include
include
include
include
SUNLIGHT
PRODUCER
HERBIVORE
CARNIVORE
DECOMPOSER
energy captured by
obtains energy by
energy captured by
obtains energy by
energy captured by
obtains energy by
energy captured by
obtains energy by
PHOTOSYNTHESIS
GRAZING
PREDATION
DECAY
energy captured by
energy captured by

Figure 1: CONCEPT MAP OF ENERGY FLOW IN AN ECOSYSTEM
(Bousquet, 1981, p. 73)

2. Related concepts are linked by lines (principles) that show these relationships; and

3. Each principle has a label that describes how the linked concepts are related.

The characteristics of the concept mapping strategy are intended to be consistent with the four educational implications of the theory of meaningful learning discussed above. The procedure asks learners to identify concepts, decide which are more general and inclusive, and meaningfully relate these concepts to each other. Furthermore, since some concepts in any learning task should be concepts with which learners are already familiar, concept maps show learners how concepts they already know relate to the new concepts they are learning. Concept mapping, once mastered, has the potential to become a generalizable strategy which students can use to meaningfully learn the concepts of any area of study.

Need for the Study

In attempting to develop and evaluate a new educational strategy such as concept mapping, several research tasks are necessary. Among the most important is refining the technique so as to effect maximum attainment of the intended learning outcomes.

Studies on the use of concept maps have been reported by Bogden (1976), Moreira (1979), D. Townsend (1981), Novak and staff (1981), and by this researcher (see Appendix A) in a pilot study.

Results of these projects have indicated that concept maps offer an opportunity for teachers to present material for students to construct meaningful relationships among concepts they encounter in educational settings. However, all authors acknowledge that their findings are preliminary in nature.

To analyze the potential, effectiveness, and limitations of concept mapping more fully, several questions are being addressed. First, can students learn the concept mapping technique? Novak, D. Townsend, and this writer have found that students master some aspects of the procedure much more readily than others. Second, what characteristics of people influence their ability to construct maps and learn from the experience? Data gathered by Novak's group (Novak and staff, 1981) show mostly low or insignificant correlations.

Third, since different approaches to concept mapping have been described (see below), which version contributes most to student learning? The necessary comparative studies have not yet been undertaken. And finally, does the act of constructing a concept map result in better learning of the concepts involved? Results of the pilot study for this research project were inconclusive, while the Novak group's investigations have shown that learners instructed in concept mapping and an additional "learning how to learn" strategy performed significantly better on subsequent conceptual tasks than did uninstructed students.

There are some differences among concepts maps presented in the literature. The original versions as described by Moreira (1979) and Stewart, Van Kirk and Rowell (1979) were primarily hierarchical in nature. Concepts were arranged from general to specific, and lines were drawn to connect related concepts. However, no words appeared on these lines.

Since concepts are propositional in nature -- that is, concepts are related to each other substantively, not arbitrarily -- later forms of concept maps that Novak and his research group developed and studied possessed the added feature of having linking words written on the lines which connected pairs of concepts (Novak, 1981; Novak and staff, 1981). These words identified the propositions (principles) by which the paired concepts were related. This version of the concept map, with both propositional and hierarchical features, is the type described above and depicted in Figure 1. In this study, it is referred to as the hierarchical-propositional (HP) concept map.

Recently, Novak (personal communication) stated that arranging concepts hierarchically sometimes makes graphic depiction of propositional relationships between concepts difficult because of the often confusing array of intersecting lines. In addition, the hierarchy in some concept groups is not clear-cut. He suggested that the general-to-specific organization of concept maps could possibly be omitted without affecting the educational value of the concept map. This proposed concept map type is termed the propositional (P) concept map for purposes of this investigation.

The existence of these three types of concept maps -- hierarchical (H), propositional (P), and hierarchical-propositional (HP) -- prompts a question raised above: Which version is most effective in promoting student learning?

Problem Statement

This study investigated the relationship of certain cognitive characteristics of learners to their ability to construct concept maps and to their gains in knowledge of environmental concepts after constructing these concept maps. Concepts were selected from among those presented in Natural Resources 201 (NR 201), Introduction to Natural Resources Management.

In addition, the hierarchical, propositional, and hierarchical-propositional versions of the concept mapping strategy were compared. This aspect of the study was conducted in order to investigate the relationship between concept learning and the hierarchical and propositional features of concept mapping.

More specifically, the research project addressed three subproblems:

Subproblem 1

At the beginning of NR 201, students' background knowledge of natural resources concepts and their level of cognitive development were assessed. This part of the investigation examined the relationship of these two cognitive characteristics to a student's performance on subsequent concept mapping tasks.

Subproblem 2

A posttest on natural resources concepts was administered as part of the regular NR 201 final exam. The concepts covered by the test questions were those which students had previously diagrammed on concept maps. In this portion of the study, the relationship of background knowledge and level of cognitive development to achievement as represented by posttest scores was investigated.

Subproblem 3

The three versions of concept mapping were compared in this part of the research project. First, the performance of students using each procedure was assessed. The second objective was to examine the relationship between performance on the concept mapping assignments and achievement on the posttest. Since this relationship may have varied with the type of concept mapping strategy used, separate correlation coefficients were obtained for each of the three concept mapping procedures. Finally, the effect of the three different versions of concept mapping upon posttest scores and attitudes was determined.

Method of the Study

The course used in this study introduces natural resources majors and interested students in other fields to basic concepts related to the management of natural resources. Two instruments were administered to all students at the beginning of the course: 1) the Preassessment of Background Knowledge, intended to measure knowledge of basic natural resources concepts; and 2) the Test of Logical Thinking (Tobin and Capie, 1980), designed to assess a student's level of cognitive development and mastery of five processes of logical reasoning.

The class (N = 132) was divided into two equal-sized groups, high prior knowledge and low prior knowledge, based upon their scores on the Preassessment of Background Knowledge. Within each group, subjects were randomly assigned to be instructed in one of three concept mapping approaches: hierarchical concept mapping, propositional concept mapping, or hierarchical-propositional concept mapping. Following instruction, each student constructed three assigned maps of natural resources concepts during the ten-week course.

Students completed a 24-item posttest on natural resources concepts as part of the regular NR 201 final examination. The participants also filled out a questionnaire designed to gain information about attitudes towards concept mapping.

Assumptions and Limitations

1. The majority of students who had taken NR 201 in past years were sophomores enrolled in their first resource management course. Therefore, pre-existing knowledge of resource management concepts was assumed to be low for students in the sample studied.
2. In previous Autumn Quarters, about 10 to 20% of course participants have been juniors or seniors who had -- for one reason or another -- taken other resource management-related courses but

not NR 201. Student grades have previously been distributed over the entire grade range, with median student achievement usually falling between C+ (77%) and B- (82%). Thus, it was assumed that a wide range of abilities and background knowledge would be represented by subjects in the study. This assumption made blocking on prior knowledge not only feasible but also advisable.

3. It was also assumed that students exposed to a given approach to concept mapping did not share their assigned procedure with students in the other two concept mapping groups. Since learning one type of concept mapping strategy required some effort on the student's part, this time requirement was a potential deterrent to the use of one technique by students who were assigned to a different version.
4. Since the target population consisted of students registered for a particular course offered by one university, this study's findings cannot by statistical logic be generalized beyond the research situation.

Definition of Terms

To quote linguist Timothy Leary, "Words are a freezing of reality." However true Leary's epigram about the limitations of concept labels may be, it is necessary to explain how certain important terms are used in this report so that the reader's reality may be momentarily frozen in roughly the same way as the researcher's, thus increasing the probability of effective communication.

1. Achievement (or Learning): The raw score attained by a student on the Natural Resources Concepts Posttest.
2. Concept: A regularity in objects and/or events, designated by a label (after Gowin, 1981, p. 29).
3. Concept Map: A graphic device for representing the conceptual structure of a discipline or a segment of a discipline (Stewart, Van Kirk and Rowell, 1979). (See hierarchical concept map, hierarchical-propositional concept map, and propositional concept map).
4. Concrete Level Reasoner: A person at the concrete-operational stage (level) of cognitive development. Concrete level reasoners can follow logical rules in thinking about actual objects and observed actions. However, persons at this level have difficulty in formulating hypotheses or following a series of related ideas unless illustrative concrete objects are available (Sund, 1976, p. 11). Operationally, a score of zero on the Test of Logical Thinking defines a concrete level reasoner.
5. Formal Level Reasoner: A person who has attained the formal-operational stage (level) of cognitive development. Formal level reasoners can perform the mental operations of the concrete stage and also have the ability to reason hypothetically, form inferences based upon assumptions, use rules of proportion and probability, and carry out mental experiments without access

to concrete referents (Sund, 1976, p. 11). Operationally, a score of four or greater on the Test of Logical Thinking defines a formal level reasoner.

6. Hierarchical Concept Map: A concept map with labels representing the most general, inclusive concept(s) located at the top of the map. As one reads downward, concepts depicted on the map are less inclusive and more specific (Stewart, Van Kirk and Rowell, 1979). No words appear on lines which link related concepts.

7. Hierarchical-Propositional Concept Map: A concept map which includes both a general-to-specific (hierarchical) organization and phrases (propositions) which describe relationships between pairs of concepts on the map (Novak, 1981; Novak and staff, 1981).

8. Level of Cognitive Development: An assessment of the general mental operations which characterize a person's thinking and learning processes. According to Piaget, children's thought patterns evolve through four stages of cognitive development: sensory-motor, preoperational, concrete-operational, and formal-operational. The latter two stages and the transition between them are of interest in this study.

9. Meaningful Learning: The type of learning that occurs when new knowledge is consciously linked by the learner to specifically relevant concepts and propositions that already exist in his or her cognitive structure (Ausubel, Novak and Hanesian, 1978; Novak, 1980).

10. Proposition (or Principle): A procedural or conceptual rule that states a relationship between a pair of concepts (Novak, 1980; Gowin, 1981).

11. Propositional Concept Map: A concept map which includes phrases that describe relationships between pairs of concepts. These propositional statements are written on lines which link related concepts on the map. Concepts are not intentionally organized into a hierarchy on this type of concept map.

12. Subsumer: A general, inclusive concept or proposition in the learner's cognitive structure to which new information may be substantively linked (Ausubel, Novak and Hanesian, 1978).

13. Subsumption: The incorporation by a learner of new knowledge into a specifically relevant concept or proposition which he or she already possesses in cognitive structure (Ausubel, Novak and Hanesian, 1978; Novak, 1980).

14. Test of Logical Thinking (TOLT): A ten-item paper-and-pencil instrument designed to assess concrete to formal levels of cognitive development (Tobin and Capie, 1980). The TOLT items are grouped into five two-item subscales, each representing a different logical reasoning pattern.

15. Transitional Reasoner: A person between the concrete-operational and formal-operational stages (levels) of cognitive development. Transitional reasoners can perform the mental operations of the concrete stage and possess at least the rudiments of formal level thought. Operationally, TOLT scores of one, two and three define transitional reasoners.

Hypotheses

The hypotheses below state the outcomes that the researcher -- before the data collection began -- expected to find.

Subproblem 1

Hypothesis 1: There will be a significant positive correlation between students' prior knowledge and their scores on concept mapping tasks.

Hypothesis 2: There will be no significant correlation between students' level of cognitive development and their scores on concept mapping tasks.

Hypothesis 3: There will be no significant correlation between the logical reasoning processes and scores on concept mapping tasks.

Subproblem 2

Hypothesis 4: There will be a significant, positive correlation between students' prior knowledge and their achievement on the posttest.

Hypothesis 5: There will be no significant correlation between students' level of cognitive development and their achievement on the posttest.

Hypothesis 6: There will be no significant correlation between the logical reasoning processes and student achievement on the posttest.

Hypothesis 7: The mean concept map score for the final (third) map which students construct will meet or exceed an 80% mastery level for all three of the concept mapping approaches (treatment groups) used.

Hypothesis 8: There will be a significant, positive correlation between scores on concept mapping tasks and achievement on the concepts posttest for students in the treatment group exposed to the hierarchical-propositional concept mapping approach.

Hypothesis 9: There will be a significant, positive correlation between scores on concept mapping tasks and achievement on the concepts posttest for students in the treatment group exposed to the propositional concept mapping approach.

Hypothesis 10: There will be no significant correlation between scores on concept mapping tasks and achievement on the posttest for students in the treatment group exposed to the hierarchical concept mapping approach.

Hypothesis 11: Students with high prior knowledge will significantly outperform students with low prior knowledge on the posttest.

Hypothesis 12: Students in the hierarchical-propositional treatment group will significantly outperform students in the other two treatment groups on the posttest. Furthermore, students in the propositional treatment group will significantly outperform students in the hierarchical treatment group on the concepts posttest.

Hypothesis 13: Students in the hierarchical-propositional treatment group will have significantly more positive attitudes towards concept mapping than students in the other two treatment groups. Furthermore, students in the propositional treatment group will have significantly more positive attitudes towards concept mapping than students in the hierarchical treatment group.

Hypothesis 14: A greater percentage of students in the hierarchical-propositional treatment group will accept concept mapping, in comparison to students in the other two treatment groups. Furthermore, a greater percentage of students in the propositional concept mapping group will accept concept mapping, in comparison to students in the hierarchical treatment group.

Plan of the Report

The research report is presented in five chapters. Chapter I discusses the problem that was studied and states the research hypotheses. A review of related literature and findings of relevant studies comprise Chapter II. Chapter III describes the methodology, including the design, treatments, instrumentation, and procedures. Results appear in Chapter IV. Chapter V includes a discussion of the results, final conclusions, and recommendations for further research.

CHAPTER II

REVIEW OF RELATED LITERATURE

The Nature and Role of Concepts

Epistemological Issues

Epistemology is the branch of philosophy which addresses questions related to the constituents and basis of knowledge. The two central concerns of epistemology are the nature of knowledge, and how knowledge is produced.

From the Renaissance through the middle of the twentieth century, the epistemological focus of science was upon a "scientific method" characterized by the dispassionate observation of nature. This view was popularized through the influential *Novum Organum* by Francis Bacon and by Karl Pearson's *Grammar of Science*.

The scientific method, as it is generally presented, consists of a series of logical steps:

1. Identify and state the problem;
2. Formulate hypotheses;
3. Gather experimental data to test hypotheses;
4. Confirm or reject hypotheses;
5. Apply conclusions to similar problems.

Scientists are supposed to be valueless and neutral; they conduct their work in a rational, unbiased manner and base their conclusions upon an objective interpretation of data.

Advances in science during the latter nineteenth and early twentieth centuries began to cast doubt upon the ideas of Bacon and Pearson. Darwin, Lamarck and their followers debated the mechanisms by which species develop and change; Einstein published his theory of relativity; Freud's insights catalyzed the emergence of clinical psychology; and sociologists such as Emile Durkheim provided new perspectives from which to examine social organization. These developments highlighted the pivotal role of concepts in formulating knowledge and helped illustrate how concepts change over time.

Conant (1947) was one of the first philosophers of science to shift attention away from studies of the logic of the scientific method and toward the changing nature of concepts. Building upon Conant's work, Kuhn (1962) suggested that major scientific progress occurs when scientists invent new conceptual viewpoints -- paradigms -- to explain experimental results or observations which could not be accounted for by existing paradigms. A paradigm, Kuhn (p. viii) explained, is a "universally recognized scientific achievement that for a time provides model problems and solutions to a community of practitioners." Paradigms thus function as both conceptual "goggles" and conceptual "blinders." They influence not only the avenues a researcher explores, they also determine what conceptual pathways are ignored.

Toulmin also stressed the epistemological role of concepts. In his introduction to Human Understanding; Part I: The Collective Use and Evolution of Concepts (1972; pp. 10-11), he asserted that

> We ... need ... to come to terms with out own intellectual creations ... we must ask:
>
> What are the skills or traditions, the activities, procedures, or instruments of Man's intellectual life and imagination -- in a word, the concepts -- through which ... human understanding is achieved and expressed?

Toulmin's arguments are based upon this premise that concepts are the basic elements of human thought and knowledge.

To portray the relationships among elements of the knowledge-making process, Gowin (1981) developed the heuristic device shown in simplified form in Figure 2. This "Epistemological V" demonstrates the interplay between the conceptual domain (concepts, principles and theory) and methodological domain (data records and statistical transformations) of the process of knowledge production.

At the "point" of the V are the observable events and objects which people seek to understand. The focus question of a given inquiry directs the conceptual and methodological sides of the V towards an examination of the particular objects and events of interest in the study. Records are gathered, statistical transformations are performed, and then the researcher formulates knowledge claims -- the answers to the focus question -- on the basis of the records, transformations, concepts, principles and theories which were used to plan, conduct and interpret the study.

Gowin's V illustrates that the focus question(s) asked, the objects and events studied, and the claims made in a given inquiry are a reflection of the investigator's conceptual paradigm. People

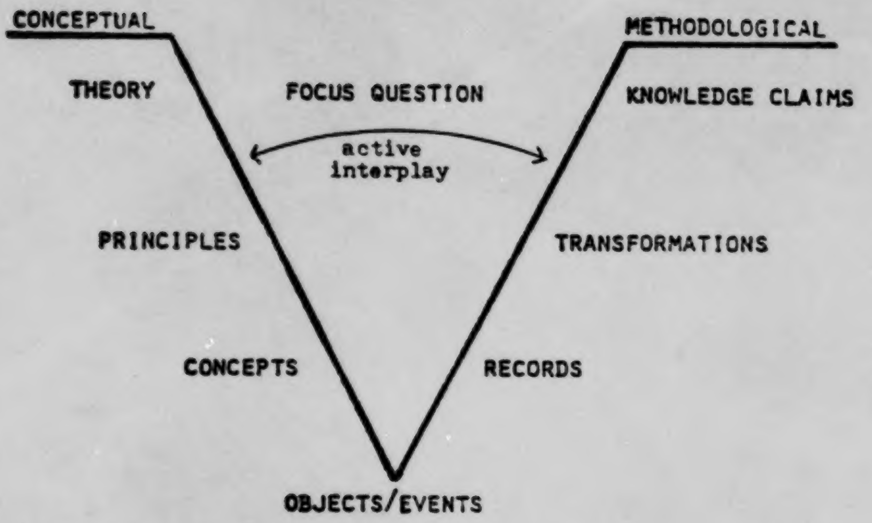

CONCEPTUAL
METHODOLOGICAL
THEORY
FOCUS QUESTION
KNOWLEDGE CLAIMS
active interplay
PRINCIPLES
TRANSFORMATIONS
CONCEPTS
RECORDS
OBJECTS/EVENTS

Figure 2: GOWIN'S EPISTEMOLOGICAL V
(after Novak and staff, 1981)

who hold to different concepts, principles and theories would pose different focus questions, observe different objects and events, and make different knowledge claims.

The "scientific method", in contrast, is simply a post hoc accounting of a scientific investigation. It reveals little about how a researcher achieved each step or how he or she progressed from one step to the next (Kuslan and Stone, 1968). To quote Nobel laureate P. W. Bridgeman (1945, p. 450), "The scientific method, as far as it is a method, is nothing more than doing one's damnedest with one's mind, no holds barred." However, the new epistemology of science provides insight into scientific thought through an emphasis upon the conceptual basis of knowledge production. The conclusion by Brown (1977, p. 166) summarizes the perspectives of Conant, Kuhn, Toulmin, and Gowin:

> Science consists of a sequence of research projects structured by accepted presuppositions [concepts] which determine what observations are to be made, how they are to be interpreted, what phenomena are problematic, and how these problems are to be dealt with. When the presuppositions of a scientific discipline change, both the structure of that discipline and the scientist's picture of reality are changed.

The Role of Concepts in Education

It has been argued that concepts are the fundamental components of scientific thought and knowledge production. Concepts, however, operate not only at the macro level of the scientific enterprise but also at the individual level. Pella (1966, p. 31) explains this:

> Concepts are important not only because they are the warp and woof of science, but also because they provide the possessor with a means of coping with the development of knowledge in the future. ... The formation of concepts or conceptual schemes is one method of classification which results in ... economical use of human intelligence.

Pines (1980, p. 1) concurs when he notes that "concepts are the basic units of learning." People filter reality through the myriad of concepts they have acquired through experience.

What a person is capable of learning in the future, therefore, is both facilitated and limited by the concepts previously learned (Ausubel, Novak and Hanesian, 1978). Quoting again from Pella (1966, p. 34):

> Because of their comprehensive nature, concepts enable the possessor to have some grasp of a much larger field of knowledge than he has personally experienced. He is able to interpret the new and to assimilate it into the old through the modification of existing concepts.

Although the use of concepts in teaching science and other subjects did not gain widespread acceptance until the 1960's, this approach had been described much earlier. In a review of the history of elementary school science, Kuslan and Stone (1968) pointed out that the elementary science program developed by Harris in 1871 centered on the basic ideas of science and their relationships to each other. Jackman's elementary science curriculum (1904) also utilized scientific generalizations as an organizational framework, and his program stressed the need for direct experience in the natural world.

The nature study movement was the dominant thrust in science education during the late 1800's and early 1900's. This perspective eventually fragmented into two school of educational thought (Weller and Caldwell, 1933). One group of educators focused upon the anthropomorphic sentiments and emotions associated with the study of the natural world, while others emphasized the use of nature study to develop students' intellects and thinking abilities. A spokesperson for the latter group was Downing, who said (1907, p. 194):

> Some unifying concept must be introduced or the course of study becomes fragmented, resulting in a series of uncoordinated efforts that lose their cumulative effect. In a course aiming to develop thought power this unifying factor would best be a series of logically related ideas or a dominant concept.

Helgeson (1968) and Kuslan and Stone (1968) agreed that one of the greatest influences on science teaching and on the conceptual approach to education was the work of Craig. In the Thirty-first Yearbook of the National Society for the Study of Education (NSSE), Craig (1932, p. 134) discussed the role of concepts in science education.

> These concepts are of fundamental importance to layment as well as to scientists... They are a part of the priceless heritage that must be passed onto future generations, and they are fundamental to intelligent living.

Craig's views, like those of Downing before him, were not extensively incorporated into educational practice. The preoccupation with education for daily life in the 1940's resulted instead in stressing the application of science to a person's everyday needs. Consequently, although an understanding of concepts was considered important, the conceptual structure of science was de-emphasized in favor of the functional use of scientific knowledge.

New ideas on constructing science curricula emerged in the 1950's as groups of scientists and science educators brought together by the National Science Foundation (NSF) decided that major revisions in science teaching were needed. Under NSF sponsorship, the Physical Sciences Study Committee began work in 1956. This group produced a high school physics curriculum that became a model for the wave of science education projects developed in the succeeding decade and a half. The majority of these programs stressed the understanding of concepts and principles instead of specific facts and definitions (Hausman, 1978). Reflecting this trend was the 1960 NSSE yearbook entitled Rethinking Science Education. In contrast to the previous NSSE yearbook on science education issued only 13 years before, the fifty-ninth yearbook attached prime importance to teaching the structure and concepts of science.

Curricula produced by the Biological Sciences Curriculum Study (Schwab, 1963) were developed around nine "themes," seven dealing with the structure of biology and two addressing methods of teaching this material. Similarly, the National Science Teachers Association (NSTA) Curriculum Committee agreed upon a set of seven conceptual schemes and five aspects of scientific methodology for organizing the science curriculum in grades one through twelve. This committee later published a revised position paper entitled "School Science Education for the '70's" (NSTA, 1971). The consideration of both the processes and the concepts of science can be seen in the statement (p. 148):

> To promote scientific literacy, science curricula must contain a balanced consideration among conceptual schemes, science concepts, and science processes, including rational thought processes, the social aspects of science and technology, and values deriving from science.

Concepts have thus become an important component and desired learning outcome of education. The development of the field of environmental education will be considered below, followed by a discussion of the mechanisms by which people learn concepts.

Environmental Education

Beginning in the early 1960's, there were growing indications that a grass roots environmental movement was taking shape. Rachel Carson's Silent Spring (1962), Adlai Stevenson's "Spaceship Earth," address (1966), passage of the National Environmental Policy Act (1969), and the first Earth Day "teach-in" (1970) were landmarks in the evolution of an increasing awareness of environmental issues in the minds of the American public.

Citizens across the nation began to understand that people depend upon and affect the condition of the environment and that, therefore, people must take action to maintain and improve environmental quality. Gallup polls indicated that the percentage of Americans supporting government action to reduce air and water pollution rose from 17% in 1965 to 53% only five years later (Swan, 1975). This concern for the environment was reflected in increased media coverage of environment-related news, a rapid growth in the membership of professional associations and conservation organizations, and the expansion and proliferation of college programs.

As Langton (1979, p. 3) pointed out, "... this movement grew from a cause to an accepted set of institutionalized American values" during the decade from the early 1960's to the early 1970's. The Environmental Protection Agency was created in 1970, followed by a succession of pieces of federal legislation dealing with issues ranging from air and water pollution to endangered species, toxic substances and strip mine reclamation.

Public support for environmental protection continues to be strong. Asked by the University of Chicago's National Opinion Center about levels of spending on domestic environmental protection programs, 50% of the 1980 respondents replied "too little" while only 15% said "too much" (Editors of EPA Journal, 1980, p. 18). Other findings of this study also confirm that the goals of the environmental movement are affirmed by a majority of the American people.

Education has been called upon to help facilitate changes in knowledge, beliefs, and lifestyles. Schools have been challenged to go beyond traditional offerings in the social studies, science and (in rural areas, especially) conservation; educational programs have also been asked to assist in providing the concepts, problem-solving skills and motivation necessary for people to act responsibly toward the environment. The term "environmental education" first appeared in the literature in 1968 (Schoenfeld, 1968). A year later, the first issue of the Journal of Environmental Education was published, and 1970 saw the formation of the National Association for Environmental Education and passage of the Environmental Education Act (PL 91-516).

Although the environmental movement of the '60's and '70's catalyzed environmental education's birth, the historical roots of the field extend much deeper to nature study, science education, outdoor education, and conservation education. These intellectual thrusts all contributed to the philosophy, structure, techniques, and focuses of environmental education (Swan, 1975; Roth, Cantrell and Bousquet, 1980).

One of the early definitions of environmental education was developed by Roth (1969) as he produced and validated a list of 111 concepts appropriate for the field. He stated (1973, p. 38) that the goal of environmental education is to develop citizens that are:

1. knowledgeable about the biophysical and socio-cultural environments of which man is a part;
2. aware of environmental problems and management alternatives of use in solving those problems; and
3. motivated to act responsibly in developing diverse environments that are optimum for living a quality life.

Representatives from around the world expressed international concern for environmental quality at the United Nations Conference on the Human Environment in Stockholm. One outgrowth of this 1972 meeting was the Intergovernmental Conference on Environmental Education, organized by UNESCO and held in Tbilisi, USSR, in 1977.

Participants enumerated recommendations for implementing environmental education at the national, world-regional and international levels. Among their guiding principles were these:

> Environmental education is the result of the reorientation and dovetailing of different disciplines and educational experiences which facilitate an integrated perception of the problems of the environment, enabling more rational action, capable of meeting social needs, to be taken.
>
> A basic aim of environmental education is to succeed in making individuals and communities understand the complex nature of the natural and built environments resulting from the interaction of their biological, physical, social, economic and cultural aspects, and acquire the knowledge, values, attitudes, and practical skills to participate in responsible and effective ways in anticipating and solving environmental problems, and the management of the quality of the environment (UNESCO, 1978, p. 23).

Using an analysis of the elements of environmental education developed by Lucas (1972), Roth, Cantrell and Bousquet (1980, p. 88) explain that the definitions above

> ...characterize environmental education as education in about, and for the environment. Education in the environment fosters a person's empathy and sense of oneness with his or her surroundings. Education about the environment enables people to understand the earth's biophysical and sociocultural environments, and education for the environment is designed to generate concern and motivate responsible action.

Furthermore, environmental education involves the three domains of learning: cognitive, affective, and psychomotor. Knowledge, beliefs, and manipulative skills are all considered essential elements in facilitating environmentally responsible behavior.

In reviews of environmental education research studies related to the cognitive domain (Roth and Helgeson, 1972; Roth, 1976), three general research thrusts were identified: 1) identification of concepts appropriate to environmental education curricula, 2) baseline studies of the attainment of concepts related to environmental education by learners, and 3) determination of the influence of various teaching and learning strategies on concept attainment.

Research in the first area of concern, the delineation of important environmental concepts, appears to have received the most attention in the literature. Investigators have developed lists of environmental understandings that were subsequently submitted for validation to panels of environmental management and education specialists (Roth, 1971; Allman, 1972; R. Townsend, 1982).

Baseline measures of environmental literacy (e.g., Perkes, 1973; Bohl, 1976; and Richmond, 1976) have indicated that students surveyed have a generally poor grasp of environmental concepts.

With regard to assessing the influence of various teaching and learning strategies on concept attainment, most studies have compared outdoor field trips with various classroom experiences such as lectures and media presentations (e.g. Brady, 1972; Howie, 1974; Hosley, 1974). In most instances, both field trips and in-class strategies have shown positive effects in helping students understand environmental concepts.

Although some progress has been made, environmental education research efforts regarding factors which influence attainment of environmental concepts can best be characterized as diffuse and uncoordinated. As Roth (1979. pp. 8-9) asserted,

> Research programs...are being developed in a few centers of learning, but far more emphasis appears to be placed on program development in most institutions rather than on researching program effectiveness. ...development of rigorous research strategies will have to dramatically increase. ...coordinated and cooperative efforts must be generated.

According to Roth, one important area in which the next environmental education research projects should be undertaken is in the initiation of baseline and longitudinal studies of teaching methods and learning strategies.

It is thus apparent that research in environmental education needs to address the effectiveness of teaching and learning techniques that are designed to promote the comprehension of environmental concepts. The mechanism by which people learn concepts are considered below.

The Psychology of Concept Learning

Introduction

If concepts are indeed the building blocks of human thought, learning, and knowledge production, then it is important for educators to understand how people acquire concepts. One of the fundamental concerns in regard to concept learning is the question of readiness. That is: What determines whether or not a person is capable of learning a concept which he or she does not already know?

A dichotomy of viewpoints has existed for several decades. Many psychologists hold that the ability to learn a concept depends upon a person's existing cognitive structure: if the person already knows concepts which relate specifically to the unfamiliar concept, then this concept can be learned. On the other hand, developmental psychologists focus their attention upon gradual, qualitative changes in intellectual capacity that proceed from a combination of maturation and experience. A person cannot learn a concept, if this group of psychologists is correct, that is more sophisticated than the mental operations that he or she is capable or carrying out.

In this section, an overview of some psychological theories related to concept learning is presented. The theories are examined primarily in terms of how they come to grips with the readiness question.

Gesell: Internal Ripening

Gesell's studies of infants' development of simple behavioral-motor functions -- e.g., grasping and walking -- led him to posit that human development is uninfluenced by environmental factors. Maturity comes about, he concluded, as a result of the expression of genetic influences over the passage of time. "Environmental factors support, inflect, and specify; but they do not engender the basic forms and sequences of ontogenesis" (1954, p. 354).

Ilg and Ames (1951) extended Gesell's embryological model of development to educational practices. They published developmental gradients, framed by age levels, for reading, writing, and arithmetic skills. Hymes, among others, concurred with this approach in saying that "All the evidence says: readiness comes about as a healthy child grows and matures. Time is the answer -- not specific drills or special practice" (1958, p. 10).

Extrapolation from a model for the development of gross motor functions in infants to both general cognitive development and readiness for learning specific kinds of subject matter has been criticized by several authors (Tyler, 1964). Brownell (1951, p. 445) argued that since "there are no known structures which are specialized to the achievement of success in subject-matter learning, ... progress ... does not come about as the inevitable result of some kind of 'unfolding'." Milner's studies (Milner, 1951) which showed that the amount and types of parent-child interactions influence the age of reading readiness in preschool children prompted Ausubel, Novak and Hanesian (1978) to maintain that relevant environmental conditions must always be accounted for when specifying a mean age of readiness.

Piaget: Stages of Cognitive Development

The psychologist whom educators most frequently cite is probably Piaget. Early in his career, Piaget became interested in the wrong answers students gave on intelligence tests. He discovered through his clinical interviews that children of different ages appeared to exhibit qualitatively different types of thinking.

In 1942, he first outlined his theory of cognitive development in The Psychology of Intelligence. As children mature, Piaget believes that their thought processes continually change and develop. Differences in these evolving mental strategies characterize the four stages of cognitive (mental) development which Piaget has identified and described: sensory-motor (birth to two years), preoperational (two to seven years), concrete (seven to eleven years) and formal (eleven to fourteen years). Three features characterize this sequence. First, although the ages at which children attain the stages varies considerably, the order of attainment remains constant. In addition, hierarchical integration occurs; i.e., later stages include the cognitive abilities of the earlier stages. And finally, each stage includes a more sophisticated set of thought processes than the stages preceeding it.

Piaget (1964) maintains that progression from one level of cognitive development to another is influenced primarily by four factors: maturation, physical experience, social experience, and a process he calls equilibration. Each of these factors is examined below.

Piaget views maturation in the Gesellian sense; that is, maturation is the "ripening" of mental abilities due to anatomical and neurophysiological development. As Piaget points out, this factor by itself is insufficient to explain a child's mental development. Studies in parts of the world as diverse as Iran, Martinique, the Australian bush country, Montreal, and Geneva confirm, to Piaget, the presence and invariant order of stages in each society. However, these same data indicate that the age at which a stage appears varies considerably from individual to individual and from society to society.

The second factor by which Piaget explains cognitive development is experience, both physical (interaction with objects) and logical-mathematical (mental activity that results from physical experience). These kinds of experience contribute to the formation of schemes; that is, mental actions that are repeatable and generalizable. As a child develops, these schemes are organized into higher-level operations -- basic cognitive processes people use to understand and act upon their surroundings.

Yet Piaget (1964, p. 159) maintains that the acquisition of many schemes and operations cannot be attributed to experience. The understanding of conservation of substance, for instance, cannot be the result of experience because:

> No experiment, no experience can show the child that there is the same amount of substance. He can weigh the ball [of clay] and that would lead to conservation of weight. He can immerse it in water and that would lead to the conservation of volume. But the notion of substance is attained before either weight or volume. This conservation of substance is simply a logical necessity.

Piaget also minimizes the role of social experience in promoting mental development. By social experience, he means the transmission of information by means of language and formal education. In Piaget's words (p. 180),

> ...this factor is insufficient [to explain cognitive development] because the child can receive valuable information via education or via language only if he is in a state where he can understand this information... he must have a structure which enables him to assimilate this information.

From a Piagetian perspective, then, a person cannot learn unfamiliar concepts unless he or she has the appropriate mental constructs (i.e., schemes and/or operations). It is primarily through equilibration, according to Piaget, that people develop these cognitive capabilities.

Equilibration is the process by which human thought continually changes and develops as a person interacts with his or her surroundings. There are two complementary ways in which equilibration occurs: 1) assimilation -- the incorporation of new information into existing schemes, and 2) accomodation -- the modification of existing schemes in light of new information. "In the act of knowing," explains Piaget (1964, p. 181), "the subject is active, and consequently, faced with an external disturbance [e.g., a novel scientific phenomenon] he will tend towards [mental] equilibrium." Similarly, Duckworth (1979, p. 302), points out that, "...it is not the pressure of data that gives rise to the understanding. It is, on the contrary, the child's own struggle to make sense of the data."

Development, to Piaget, is not the cumulative result of a set of specific learning experiences. Instead, development explains learning. Therefore, in Piaget's view, progress from one level of mental development to the next cannot be accelerated by instruction related to a particular scheme or operation.

It is equilibration, not specific instruction, that is the fundamental influence upon development; development is thus the cumulative effect of episodes of equilibration. That is, "All the emphasis is placed on the activity of the subject himself, and I think that without this activity there is no possible didactic or pedagogy which significantly transforms the subject..." (Piaget, 1964, p. 185).

Scientists and educators who spearheaded several of the science, social studies, and mathematics curriculum projects in the 1950's and 1960's claim that Piaget's approach has greatly influenced their efforts (e.g., Karplus and Thier, 1968). However, the work of Piaget has been sharply criticized on both theoretical and empirical grounds.

Since Piaget's interest is in general mental operations and not specific learning experiences, the question arises as to whether his theory applies to classroom situations where the focus of instruction is upon discrete areas of content. Wollman (1978), also a developmentalist, provides a summary of the concerns many educators and educational psychologists have voiced about the implications of Piagetian theory for education (p. 24):

> Piaget...focuses on the logical relations he believes to be essential to each task while ignoring the specific content of tasks. Since Piaget's theoretical description of performance omits mention or even consideration of content, his theory cannot, by design, account for the role of content. ...
>
> Only a moment's reflection should be needed to see that the omission of these details leaves a great and vital gap from the educator's point of view. ... Transfer of learning, a universal goal, means transfer of structure to new content. Thus a word of caution: even if Piaget's theory were perfect and complete, there would remain the problem of application to the diversity of content... .

The predictive and theoretical validity of the four stages themselves has also come under fire. Although it seems reasonable to assume that each human undergoes age-related periods of cognitive development, studies reviewed by Dasen (1972) demonstrate that a sizable percentage (in some cases, even a majority) of adults fail to reach the stage of formal operations. Several other investigations, including those by McClelland (1970), Nussbaum and Novak (1976) and Friedman (1977) showed that a substantial number of six and seven-year-olds can demonstrate formal reasoning abilities with novel science phenomena after experiencing related audio-tutorial instruction. Data such as these prompted Novak (1977b, p. 394) to declare:

> ... we must begin to ask "when is a stage not a stage?" The answer is obviously "when nothing consistent is reliably denoted by a stage." Thus, we must argue that efforts to describe cognitive developments in terms of _stages_ must eventually go the same way as the epicycle model for the homocentric universe.

Piaget himself (Piaget, 1972) reported that some students in his studies were at the formal stage on one task but demonstrated only concrete operations when given another task to analyze. He termed this phenomenon _decalage_, but argued that such inconsistency of performance occurs only when subjects fail to see how what they know applies to a given situation.

On the other hand, Wollman (1978, pp. 25, 25) asserts that:

> ... the predictive power of Piaget's theory is too weak... empirically, decalage is the rule, not the exception... Piaget's stage notions do not help us understand what has or can be learned.

Wollman cites numerous studies which support his argument that Piaget's classification of performance as concrete or formal fails to produce homogeneous groupings of students. For educators and educational psychologists, decalage has turned out to be the Achilles' heel of Piagetian theory. Decalage, according to Odom (1978), has considerably weakened faith in the usefulness of the theory, if not the theory itself.

Nevertheless, the limitations of Piaget's theory do not negate the validity of a developmentalist perspective on learning. Neo-Piagetian researchers have investigated other mental reasoning strategies that may provide insight into the cognitive processes associated with concept learning. These efforts will be discussed after other viewpoints on the psychology of concept learning are examined.

Bruner: Discipline Structure and Mental Representations

Much of what Bruner has said about concept learning and cognitive development is derived, in part, from a Piagetian paradigm. However, Bruner has added several dimensions to learning theory and he diverges sharply from Piaget on several points.

Bruner (1966, pp. 10-14) reanalyzed Piaget's developmental stages, transforming them into three types of mental operations that humans use to encode, store and retrieve information. During a person's infancy, objects and events are usually defined by means of actions; e.g., "a bottle is to suck on" or "Mommy's hair is to grab." This form of representation is termed the enactive mode. Later, representations of one's surroundings come to depend not only upon actions but also upon sensory cues and organizational patterns. Children using this, the _iconic_ mode, can reproduce a specific arrangement of blocks, for example, but they are not yet capable of manipulating the pattern mentally unless such rearrangement is demonstrated beforehand. Eventually, a child begins to use words and language to encode and perform operations upon objects and events. This is the _symbolic_ mode of representation.

It is Bruner's contention (p. 21) that the primary emphasis in instruction should be in "providing aids and dialogues for translating experience into more powerful systems of notation and ordering." Although younger school children may be less able than older students at representing knowledge in the symbolic mode, they are still capable of some uses of words and language to code their perceptions. This is what Bruner means by his oft-quoted statement (1960, p. 33) "We begin with the hypothesis that any subject can be taught effectively in some intellectually honest form to any child at any stage of development." From this assertion comes the notion of the "spiral curriculum" in which, according to Bruner (p. 13),

> The early teaching of science, mathematics, social studies, and literature should be designed to teach these subjects with scrupulous intellectual honesty, but with an emphasis upon the intuitive grasp of ideas and upon the use of these basic ideas. A curriculum as it develops should revisit these basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them.

Mental growth can, in Bruner's opinion, be facilitated to a considerable degree by environmental influences, particularly those directed by teachers and other "agents of the culture."

Bruner has also emphasized the need for students to learn a discipline's structure; i.e., its fundamental principles and concepts. In The Process of Education (1960, pp. 17-18), he states:

> ...earlier learning renders later performance more efficient...through...the transfer of principles and attitudes. In essence, it consists of learning initially not a skill but a general idea... The more fundamental or basic is the idea...learned, almost by definition, the greater will be its breadth of applicability to new problems.

Thus, Bruner is a developmentalist in that he speaks in terms of a series of general modes of mental representation which people gradually come to master. In addition, however, he has stressed the role of specific learning experiences in promoting the acquisition of concepts. No matter how sophisticated a person's general mental capabilities might be, an understanding of a particular discipline's fundamental concepts is an essential prerequisite to further knowledge gains in that subject area.

Ausubel and Novak: Meaningful Learning

Meaningful learning, as outlined in Chapter I, is an internal cognitive process which involves the interaction of new information with related knowledge that a person already possesses. Concepts become more fully understood as the learner continually adds connections to associated concepts. This elucidation and extension of concept meanings is the means by which each person develops a unique, experience-based hierarchy of concepts in cognitive structure.

In order for meaningful learning to occur, Ausubel maintains that two conditions are necessary. First, the learner must manifest a meaningful learning set; that is, a disposition to consciously relate unfamiliar concepts to his or her existing cognitive structure in a substantive, logical fashion. Second, the learning material must be potentially meaningful to the learner. This presupposes that 1) the learning material itself has logical meaning, and 2) the learner already knows concepts that can be substantively related to the learning material (Ausubel, Novak and Hanesian, 1978, pp. 41-42).

According to Ausubel, (Ibid, p. 208), meaningful learning has a dual influence upon a person's readiness for subsequent learning.

> On the one hand, it determines specific readiness for particular kinds of subject matter learnings... . On the other hand, it also contributes to general changes in cognitive readiness that are, at least in part, independent of the kind of subject matter studied.

For example, studying electrical circuits in fourth grade helps prepare students to investigate atomic structure and electromagnetic fields in their high school physics classes. In addition to this readiness for learning new but related subject matter, learning experiences also influence a person's development of progressively more abstract modes of cognitive functioning. Ausubel calls the specific, quantitative type of readiness subject-matter readiness. He refers to a person's general, qualitative stage of cognitive maturity as developmental readiness.

Specific episodes of concept learning are seen by Ausubel, therefore, as contributing to both types of readiness that he has identified. Another factor, however, also exercises an influence (Ibid, p. 249):

> ...the more general nonexplicit instances of intellectual capacity...are general long-term resultants of diverse, nonspecific experience. ...New learning is influenced both by specific prior learning and by more general developmental variables.

Here is where Ausubel's views differ somewhat from those of Novak, who has written much about meaningful learning and used the theory as the basis for his own research. Novak (1977a, p. 97) argues that

> ...a child is ready for meaningful learning in any subject area for which he has some specific, relevant subsuming concepts. The issue is related to age only because older children tend to have more and better differentiated concepts than younger children.

Novak and Ausubel agree that existing concepts are the most important influence upon future learning. However, Novak does not find developmental periods a useful construct, believing (Ibid., pp. 122-123) that "all of these periods can more parsimoniously be explained in terms of development of specific cognitive conceptual hierarchies with progressively greater degrees of inclusiveness and differentiation."

Summary of the Psychological Theories

The issue raised at the beginning of this review of the psychology of concept learning concerned influences upon a person's ability to learn an unfamiliar concepts. Much of the literature cited dealt with this question in terms of readiness.

Gesell attributes readiness to genetically-influenced maturation. It is difficult, however, to defend the extrapolation of his work on gross motor functions to cognitive development. To Piaget, progression from one level of cognitive development (hence, one level of readiness) to another is determined primarily by maturation, physical and social experience, and equilibration. Equilibration -- a person's mental struggle to make sense out of his or her perceptions -- is the most important of these. The predictive validity of Piagetian theory, significantly weakened by the confounding influence of decalage, limits the application of his work in cases where specific instances of concept learning are considered.

Bruner and Ausubel each discuss two kinds of readiness: developmental readiness and subject-matter readiness. Both discrete instances of subject-matter learning and non-specific experiences that contribute to general mental development are believed to be factors which influence a person's capability of learning new concepts. Novak, an advocate of Ausubel's meaningful learning paradigm, rejects the predictive power of developmental stages. To Novak, readiness can be explained completely by the particular concepts the learner has in his or her cognitive structure.

As Brownell (1951) points out, there is readiness as defined and debated by theorists and then there is readiness as employed by a teacher in making daily decisions. The question which, therefore, arises is this: Which type of readiness, developmental readiness or subject-matter readiness, plays a greater role in determining whether or not a person is capable of the types of learning that are important in educational situations? Should a teacher be concerned primarily with the concepts a child already knows, primarily with that child's stage of intellectual development, or should weight be given to both factors? If learning theory is to have practical application to the classroom, the question posed here must be investigated. Some evidence has been gathered, and several relevant studies are discussed below.

Concept Learning Research

Research on Meaningful Learning

Most research on the theory of meaningful learning has dealt with the instructional use of what Ausubel calls advance organizers. As defined by Kozlow (1978, p. 18), an "advance organizer is a set of introductory instructional materials designed to establish a concept in cognitive structure which can serve as a subsumer for the detailed learning materials to follow." Reviews (Mayer, 1977; Ausubel Novak and Hanesian, 1978) and meta-analyses (Kozlow, 1978; Luiten, Ames and Ackerson, 1980) of research on advance organizers generally support the effectiveness of properly-constructed organizers but indicate that the strategy may be more beneficial to certain types of learners.

Ausubel, Novak and Hanesian (1978, p. 167) assert that an organized body of conceptual knowledge is more than just a dependent variable to be used in the assessment of variables which affect learning. "This knowledge (cognitive structure), once acquired, is also in its own right the most significant independent variable influencing the learner's capacity for acquiring more knowledge in the same field." For this reason, Novak (1977a, p. 220) advocates utilizing "what the learner already knows" as an independent variable in the studies of the effects that various instructional treatments have upon achievement.

Tamir (1968) studied achievement in an introductory college biology course and found that students improved most in areas in which they had the best pretest scores. Similarly, Novak (1977a) reported that Ring (1969) showed that chemistry achievement, as measured by combining scores on lecture exams and lab quizzes, exhibited a strong linear relationship with scores on a test which measured subsuming concepts possessed by students prior to instruction. Following the leads of Tamir and Ring, Wesney (1977) demonstrated that success in learning physics concepts was predicted not by differences in ability (I.Q.), but rather by adequacy of relevant concepts in algebra and science. These studies help validate Ausubel and Novak's emphasis upon the contribution of existing knowledge to subsequent learning.

A researcher operating from a Piagetian paradigm would be unlikely to attempt to teach abstract concepts to lower elementary school students because Piaget maintains that instruction has littie, if any, influence upon mental development and that children are not expected to attain the stage of formal operations until they are twelve years old. However, studies by Novak's research group (McClelland, 1970; Nussbaum and Novak, 1976; and Friedman, 1977) showed that after audio-tutorial instruction in science concepts a sizable proportion of six and seven year-old children were capable of abstract reasoning on those topics. For example, Novak (1977a,c) reported that McClelland developed five 20-minute units on energy and energy transformation for second graders. On the basis of interview responses, McClelland found that 55 to 82% of these young children could satisfactorily recognize instances of these concepts in unfamiliar contexts. Approximately 25% could give formal explanations for their observations. In Novak's words (1977a, p. 240),

> ...it was evident that many of the students were not simply repeating answers given in the lessons but were using concepts of energy and energy transformation in novel problem solving situations. ...This was our first hard evidence that Ausubel's model was more appropriate than Piaget's for describing children's development of concepts.

It should be noted that Novak did not say that Ausubel is right and Piaget is wrong. He simply pointed out that the meaningful learning paradigm offered a more adequate explanation for McClelland's results. The following studies also call the Piagetian model into question and lend additional support to Novak's Ausubel-based viewpoint.

Karplus and Karplus (1970) studied the logical reasoning abilities of people in five groups: fifth and sixth graders, seventh through ninth graders, tenth through twelfth graders, twelfth-grade physics students, NSTA Convention participants at a Piaget symposium, and participants at a professional meeting of physics teachers. The problem the Karpluses asked subjects to analyze dealt with plane routes among four islands. An adequate, generalizable explanation based upon clues which the Karpluses provided required formal thought. The Karplus data showed that success on the puzzle improved with age from grade five through high school, but teachers at the NSTA symposium were outperformed by the high school physics students. Physics teachers did much better than all other groups. The Piagetian notion of developmental stages cannot explain the considerable difference in success between the physics teachers and NSTA participants; there is no reason to suspect that the general cognitive development of physics teachers is significantly greater than that of the science teachers at the NSTA convention. In addition, one would expect that the college-educated NSTA teachers were at least as developmentally advanced as the students taking twelfth-grade physics. Since the physics students and physics teachers most probably had greater knowledge of concepts related to vectors than did the NSTA participants, Karplus and Karplus appear to have substantiated Ausubel's assertion that the most important factor in learning is the adequacy of the learner's existing relevant concepts (Novak, 1977a).

A person's capacity for "formal operations," therefore, seems to be more content-specific than age-specific. This, by itself, certainly does not invalidate a theory based upon developmental stages, but it does call into question the applicability of such a paradigm to concept learning in school settings.

If relevant subject-matter knowledge is a more important factor in readiness than stage of cognitive development, then a student's performance on one concept-specific task should be a better predictor of success on a related concept-specific task than that student's performance on any Piagetian task. This, in essence, was one of Whitman's (1975) principal findings in a study of second-graders' knowledge gains subsequent to audio-tutorial instruction in molecular theory. Through her interviews, Whitman assessed each student's performance on five Piagetian conservation tasks and eight tasks related to concepts introduced in the audio-tutorial lessons. Only two of 35 correlation coefficients between science tasks and Piagetian tasks were significant, and for these two the correlation was low. However, out of 21 correlation coefficients among science tasks 19 were significant, with very closely-related tasks sharing up to 68% of common variance. These results lend further support to the meaningful learning paradigm as an aid to understanding concept learning in educational settings.

An analysis of research findings reviewed by Novak, Ring and Tamir (1971) provides guidance in the construction of pretests and post-instruction achievement tests which attempt to measure conceptual knowledge. Over 50 correlational studies were found in which prior knowledge in one subject area was the best predictor of subsequent performance in the same or a related discipline. Biographical data, general ability, and personality and interest measures were generally less effective predictors of academic success than were more specifically concept-oriented instruments. However, 16 studies examined showed no relationship between cognitive pretests and achievement. Novak and his colleagues (Ibid., p. 517) indicate that

> Many tests used as predictors measure primarily factual knowledge; these tests appraise primarily the degree of overlearning of specific facts of a discipline and scores are almost unrelated to the relative adequacy of concepts in a learner's cognitive structure.

These writers postulate that the best predictor of achievement in a given subject area would be a student's performance on a small learning task related to that subject. A student who can obtain a high score after only briefly examining some learning material probably has a more highly differentiated cognitive structure in that discipline than students who perform poorly on such a task. "Conceptual questions" designed according to this recommendation were used in a subsequent study by Novak's group (Novak and staff, 1981). (Results of that investigation are discussed below in a section on concept mapping research.

Thus, the findings of a number of studies appear to support the contention that subject-matter specific knowledge helps explain more of the variability in students' conceptual knowledge following instruction than do measures of Piagetian developmental levels. Developmentalists have gone beyond Piaget's work, however. Newer frameworks of cognitive development, some of which are outlined in the following section, may prove to be of more use in understanding concept learning.

Neo-Piagetian Research

Overview

For educators and educational researchers, Piaget is more than the most influential developmental theorist. Wollman (1978, p. 6) points out that Piaget's work "is the point of departure even for those who make an issue out of differences with his theory." Piaget, however, left to others the task of applying his theory to educational practice. The bulk of these efforts have been undertaken in the past two decades, particularly in connection with or as an extension of nationally-disseminated curricula.

Attempts to extend and modify Piaget's theory are frequently grouped and termed "neo-Piagetian." In addition to focusing upon the classroom relevance of developmental psychology, the neo-Piagetian approach generally involves suggesting more specific constructs by which development might be explained and studied, and investigating logical reasoning patterns which characterize the concrete and formal stages.

Encoding Ability

Siegler (1976) developed a task analysis research methodology which allowed him to describe and predict patterns of response to instruction. Instead of looking to global stage-related mental abilities, Siegler's view of development is more sharply focused. A person's developmental level limits his or her ability to encode information. For reasons not yet understood, a learner begins to encode stimuli that go beyond the needs of the problem-solving rule that is typically used by persons at that learner's developmental level. This new information initiates a mental reorganization process which leads to the formulation of a new rule and hence a new level of cognitive development.

Although Siegler's view of development appears similar to Piaget's notion of assimilation, "there is one crucial difference between the two formulations: it is possible to independently measure encoding, whereas no means have been devised to measure assimilation" (*Ibid*., p. 516). Because encoding is measurable, prediction becomes possible.

Siegler's investigations of encoding ability and studies of working memory space conducted by Case (1972, 1979) represent attempts to interpret Piaget's theory from an information-processing paradigm. The objective is to identify specific constructs which will make more advanced research designs and theoretical analysis possible.

Logical Reasoning Patterns

Several investigators (e.g., McClelland, 1970; Nussbaum and Novak, 1976; Wollman, 1975) have observed that lower elementary school children appear to have some formal reasoning capability, at least at the intuitive level. Such results suggest that appropriate instructional sessions would enable concrete level reasoners to utilize formal modes of thought with respect to specific concepts or thinking processes (Lawson and Wollman, 1976).

Much neo-Piagetian research has been directed toward this end. Investigators have examined the modes of logical reasoning which underlie Piaget's general notions of concrete and formal thought. As defined by Karplus (1979, p. 151), a reasoning pattern is "an identifiable and reproducible thought process directed at a type of task." Although numerous patterns have been discussed, science educators have recently focused attention upon a group of five: proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning (Lawson, 1978).

A study by Lawson and Wollman (1978) showed that a set of specially designed instructional sessions could promote the transition from concrete to formal reasoning in fifth-and seventh-graders with respect to their ability to control variables. Other modes of reasoning were unaffected by the instruction, which focused only upon controlling variables. As the researchers (p. 427) pointed out, the training increased the decalage between the ability to control variables and other aspects of formal thought.

Examination of logical reasoning patterns may provide more precise descriptions of cognitive development and offer measures which explain a greater amount of variability in student performance than would the simpler categorization of development into concrete or formal stages.

Research on Concept Mapping

Studies involving concept maps have been conducted by Rowell (1975), Bogden (1977), Moreira (1979), D. Townsend (1981), Novak and staff (1981) and by this researcher in a pilot study (see Appendix A).

Rowell (1975) used concept mapping in his study of first graders' ability to use conceptual models to explain natural phenomena presented in an audio-tutorial science program. To assess children's understanding and use of mental models such as a food chain and the continuity of life, Rowell constructed a concept map of each unit and used this map to guide his student interviews. He presented children with pictures and objects related to the material they had studied, asked the students questions about the relationships among these objects, and then graphically depicted the concepts and principles each child described by constructing a concept map from the tape transcripts. The resulting maps were rated according to the degree of model-using represented. Although Rowell's study did not investigate the instructional uses of concept maps, his use of the technique as a research tool represents one of the first attempts to employ concept mapping to depict the relationships among concepts in an area of study.

In a college physics course, Moreira (1979) ended each unit with a map of the important concepts covered. Bogden (1977) constructed a concept map for each of a series of genetics lectures and used them as the focus of student discussion sections. In both courses, the concept maps were used to summarize the important ideas in each course segment. The maps served as supplements to readings, lectures, and laboratories for some students, while others used the concept maps as aids in reviewing course material.

Moreira's maps followed the hierarchical format. They displayed a general-to-specific hierarchy from top to bottom, but the propositions which linked depicted concepts were not labeled. (At the time of Moreira's study, the practice of labeling propositions was not yet in use). The control group made no use of concept maps. A "concept mapping test," consisting of a list of concepts and simple concept mapping instructions -- which did not include the instruction to arrange concepts hierarchically -- was administered following instruction. Moreira reported that students in the experimental group had a greater tendency to 1) draw maps that displayed a vertical hierarchy, and 2) select better examples of general concepts than did control group students. An attempt to quantify these apparent differences was not made in this largely exploratory study of concept mapping.

D. Townsend (1981) taught two twelfth-grade physics classes the use of the hierarchical-propositional concept mapping technique. After constructing several maps, these students evaluated concept mapping by means of a semantic differential instrument. Townsend noted some common student errors in making concept maps. In particular, he reported that students often neglected to label the propositions that connected concepts with an appropriate linking word or words.

In a pilot study for the present research project, this writer attempted to 1) determine the effect of concept map use upon student achievement, 2) compare written and oral concept mapping instructional programs, and 3) assess student attitudes toward selected aspects of concept mapping. Volunteers (N=53) from the Spring Quarter, 1981, NR 201 class were assigned to one of three treatment groups. A control group was not shown how to make concept maps; the second group used a packet of written materials to learn the strategy; and the remaining students participated in a 50-minute group instruction session on concept mapping.

No significant differences in attitudes or in concept map scores were found between the group that used written instructions and the group which was instructed orally. Opinions expressed on the attitude assessment suggested improvements to the instruction program and showed that students believed concept maps had the potential to help them learn environmental concepts of the type presented in NR 201. However responses were diverse, averaging out to "neutral," on items which dealt with how students felt about their competence in making concept maps and their plans to construct additional maps in the future.

A breakdown of concept map scores by the five evaluation criteria indicated that subjects had particular difficulty in identifying content-correct conceptual relationships and delineating concept map branches and cross links. These findings suggested that more time in a concept mapping instructional program should be devoted to assisting students in making their own concept maps and to providing feedback on completed maps. A summary of the pilot study appears in Appendix A.

Novak and his colleagues at Cornell University (Novak and staff, 1981) studied the use of concept mapping and a mapping strategy based upon Gowin's epistemological V. The project spanned two school years and involved junior high students in four Central New York school districts. Among the questions addressed (P. 1-2) were:

> Can seventh and/or eighth grade science students learn to use concept mapping and "V" mapping strategies in conjunction with existing science programs?
>
> Will students' acquisition of science knowledge and problem solving performance change as a result of the strategy?

> Will students shift toward a more positive attitude
> about science?

The project also involved refining the design, implementation and evaluation of the two learning strategies.

The researchers found that junior high pupils could learn concept mapping, and that they were able to use the technique in conjunction with their readings and laboratory work. Students, on the whole, gradually improved in their ability to construct concept maps. Although students in the highest quartiles on standardized achievement tests showed the best mapping performance, some pupils in all quartiles were able to construct adequate maps. In general, students understood the "conceptual relations" and "hierarchy" features of the concept maps, but they had more difficulty in constructing maps which exhibited branching and cross links. Novak and his colleagues (*Ibid*., pp. IX-11 X-2 to X-3) suggested that students would have made more adequate maps if the rules for concept map construction and the five assessment criteria had been given more emphasis. This recommendation is similar to ones made by Townsend and by the author, discussed above.

Attitudes toward four general areas of science education were evaluated prior to and following instruction by means of an 18-item Likert-type instrument. Some classes and student groups showed significantly positive changes in attitudes in most of the categories but no definite patterns were discerned.

To determine if the two strategies -- concept mapping and V mapping -- effected knowledge gains that resulted in improved ability to solve problems or to apply learned concepts to new areas, the research team developed "conceptual questions" for students to analyze. Mean scores of student groups instructed in concept mapping and V mapping were significantly higher than those of the uninstructed groups, even though neither learning strategy was necessary to provide adequate answers to the conceptual questions.

Several correlational analyses were performed with ability to construct a concept map, as measured by the concept map scoring criteria, as the dependent variable. Low or insignificant relationships were found between concept mapping skill and science grade, science final exam grade, SAT verbal score, and SAT math score. A significant correlation was found, however, with SCAT scores (verbal, $r = .34$; quantitative, $r = .31$), which suggested that the SAT and SCAT measured somewhat different abilities. Although concept mapping performance was not correlated with skill in using the V in laboratory exercises, concept mapping correlated significantly ($r = .36$) with ability to identify, define, and select examples of the V terms (_Ibid_., pp. IX-30 to IX-35).

Surprisingly (to this writer, at least), correlations between concept mapping scores and performance on the conceptual questions were insignificant and near zero. To Novak and his group (p. IX-30), "This suggests that different cognitive performances are required in the two tasks and, therefore, we see these evaluation tools as complementary rather than redundant." These researchers did not report correlations with the five separate criteria used to evaluate concept mapping ability; only the total score was used in the reported analyses.

Implications of the Literature for the Study

On both philosophical and psychological grounds, the literature discussed in this chapter justifies the importance of concepts in thinking, teaching, and learning. Concepts are a significant component of educational programs including those in environmental education.

Readiness for learning a given concept appears to depend upon the specific concepts a learner knows and, possibly, upon the learner's more general mental capabilities. While there is empirical evidence to support basic tenets of Ausubel's theory of meaningful learning, researchers in developmental psychology have found that Piagetian stages do not help explain concept learning in educational settings. Ausubel's work can be elaborated by examining how learners utilize applications of meaningful learning theory, such as concept mapping. The relationship between concept learning and neo-Piagetian developmental constructs, such as Lawson's logical reasoning processes, also needs to be explored more thoroughly.

If meaningful learning theory is correct, the concepts a student knows prior to instruction in a related area should have a significant effect upon subsequent learning. On the other hand, if cognitive development is a more important factor in concept learning than is specific conceptual knowledge, a student's stage of cognitive development (or that person's logical reasoning ability) should be a stronger predictor of achievement than that person's background knowledge.

Performance on a concept mapping task can be viewed as a dependent variable to compare the explanatory power of Ausubelian and Piagetian theories. Concept mapping task performance can also function as an independent variable to predict student achievement following instruction and concept mapping. Since concept maps can display a hierarchical organization, propositional relationships, or both, concept mapping offers a vehicle for comparing how hierarchies and propositions assist students in learning concepts.

CHAPTER III

RESEARCH PROCEDURES

Design

Population and Sample

The target population was students enrolled in Natural Resources 201 (NR 201), Introduction to Natural Resources Management, at The Ohio State University. The sample used in this study was the 132 students registered for NR 201 during Autumn Quarter, 1981. All students in the course were involved in the research project. Participation in the treatment groups and completion of the tests and concept mapping assignments was made a regular, integrated part of NR 201.

Natural Resources 201 is a three-credit course intended to cover basic topics related to natural resources and their management. Among the areas addressed are: ecological principles, the history and philosophy of resource management, economic and political influences upon resource management decisions, and planning for future challenges. In addition, approximately half of the course is devoted to a consideration of the management of specific resources: water, soils, minerals, energy, forests, wildlife, air, and recreation resources. Appendix B contains the course schedule for Autumn Quarter, 1981.

The course is taught by a faculty member from the School of Natural Resources' Division of Environmental Education who is assisted by a Graduate Teaching Associate. Guest speakers from various natural resources field present about half the lectures. Two midterms and a final examination are given, and students complete ten short writing assignments.

Assignment of Treatments

At the beginning of the course the Preassessment of Background Knowledge, designed to measure students' existing knowledge of natural resources concepts, was administered. The class was then divided into two equal-sized groups, designated as high prior knowledge or low prior knowledge, based upon their preassessment scores.

Within each of these two groups, students were randomly assigned to one of three concept mapping treatment groups: hierarchical-propositional concept mapping (HP), hierarchical concept mapping (H), and propositional concept mapping (P). This 2 x 3 factorial design permitted comparison of the three concept mapping treatments for both high and low prior knowledge levels. In addition, comparisions could be made for each of the two levels of pre-course knowledge (Kennedy, 1978).

Using the notation developed by Campbell and Stanley (1963), the basic research design for this study may be diagrammed as follows:

$$\begin{array}{ccc} R & X_1 & 0 \\ R & X_2 & 0 \\ R & X_3 & 0 \end{array}$$

where R indicates that subjects were randomly assigned to treatment groups; 0 represents the concepts posttest which all groups took; and X_1, X_2, and X_3 represent the three concept mapping treatments. This scheme is a variation of Campbell and Stanley's posttest-only control group design. Instead of the usual control group and experimental group, the design for this study includes three comparison groups: X_1, X_2, and X_3.

Treatments

Students in each prior knowledge group were randomly assigned to one of three treatment groups. Students in each treatment group were instructed in the appropriate concept mapping strategy by means of slide-tape auto-tutorial modules supplemented by written materials. Scripts and workbooks for these modules appear in Appendix C. Modules required approximately one hour for students to complete and were available at two campus locations. The validation of the three modules is described below under Procedure.

Group 1: Hierarchical-Propositional Concept Mapping (HP)

These students were instructed in the concept mapping procedure described in Chapter I and by Novak (1981; Novak and staff, 1981).

This version of concept mapping is the one currently used by Novak's research group. Hierarchical-propositional concept mapping (HP) involves the steps summarized below:

1. Identify the concepts to be mapped. Write each on a slip of paper.
2. Arrange concepts from most general to most specific.
3. Group concepts which are related to each other.
4. Identify the propositions (linking phrases) which verbally link related concepts.

5. Organize the concepts and propositions in a manner that preserves the general-to-specific hierarchy while depicting the identified propositional relationships among the concepts. Draw the resulting concept map, making sure to label the lines with the propositional phrases that describe the relationship between linked concepts.

Group 2: Hierarchical Concept Mapping (H)

This group of students learned the concept mapping procedure initially used by Novak's group and described by Stewart, Van Kirk, and Rowell (1979) and Moreira (1979).

Hierarchical concept maps (H) possess the general-to-specific concept hierarchy of hierarchical-propositional concept maps. However, in the hierarchical approach the propositions are not identified; no words appear on the lines which connect related concepts portrayed on the concept map. The following steps comprise the hierarchical concept mapping strategy:

1. Identify the concepts to be mapped. Write each on a slip of paper.
2. Arrange concepts from most general to most specific.
3. Group concepts which are related to each other.
4. Organize the concepts in a manner that preserves the general-to-specific hierarchy and indicates the links between related concepts. Draw the resulting concept map.

Group 3: Propositional Concept Mapping (P)

Students in this treatment group (P) were told to formulate phrases that describe relationships between pairs of concepts. These propositional statements were written on lines which linked related concepts. In the instructional materials, no reference to a hierarchical organization of concepts was made. Examples presented were intentionally constructed without hierarchical ordering. Thus, the approach presented to students in this group involved the following steps:

1. Identify the concepts to be mapped. Write each on a slip of paper.
2. Group concepts which are related to each other.
3. Identify the propositions (linking phrases) which verbally link concepts.
4. Organize the concepts and propositions in a manner that depicts the identified propositional relationships among the concepts. Draw the resulting concept map, making sure to label the lines with the propositional phrases that describe the relationships between linked concepts.

This procedure was suggested by Novak's comments that deciding which concepts are "general" and which are "more specific" is often difficult; many hierarchies can be turned around and still have meaning (Novak, personal communication). In working with ConSAT, a procedure similar to concept mapping, Champagne, et al., (1978) reported a similar observation. They indicated that integrating hierarchical and propositional relationships on a single diagram can mask some of the subtleties depicted on separate hierarchical and propositional diagrams.

Summary of Treatments

To clarify differences among treatment groups, the characteristics of the three concept mapping procedures are summarized below in Table 1.

Table 1

Comparison of Characteristics of Concept Mapping Procedures

	Concept Mapping Procedures		
Characteristics	Hierarchical-Propositional (HP)	Hierarchical (H)	Propositional (P)
1. Concepts identified	X	X	X
2. General-to-specific organization	X	X	
3. Related concepts grouped	X	X	X
4. Related concepts linked by lines	X	X	X
5. Propositions written on lines	X		X

Instrumentation

For this study, eight instruments and evaluation procedures were utilized: 1) Preassessment of Background Knowledge, 2) Test of Logical Thinking, 3) Background Questionnaire, 4) Hierarchical-Propositional Concept Map Scoring Procedure, 5) Hierarchical Concept Map Scoring Procedure, 6) Propositional Concept Map Scoring Procedure, 7) Natural Resources Concepts Posttest, and 8) Concept Mapping Attitude Assessment. These instruments are described below.

Preassessment of Background Knowledge

This multiple-choice instrument was designed by the writer to measure students' knowledge of natural resources concepts at the beginning of NR 201. The test, as administered, consisted of 30 items and is contained in Appendix D.

Because of time constraints, the instrument was not submitted to a review panel until after it was given to NR 201 students. This panel consisted of eight Ohio State University natural resources and science education faculty members. Panelists marked the responses which they thought best answered each item. In addition, panel members were asked to identify questions in which the wording was unclear and questions which could have more than one legitimate answer.

A criterion of 75% acceptance (i.e., 6 out of 8 reviewers agreeing) was established. Based upon panelists' comments, five items were eliminated and two of the remaining questions were keyed with two correct answers. The remaining 25 items comprised the posttest.

Test of Logical Thinking

The Test of Logical Thinking (TOLT) is a ten-item paper-and-pencil instrument designed to assess concrete to formal thought; it appears in Appendix E. Comprising the TOLT are five two-item subtests for the logical reasoning processes identified by Lawson (1978): propositional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning. Tobin and Capie (1980), who developed TOLT, reported an internal consistency reliability (coefficient alpha) of 0.85 for 682 students in sixth grade through college. The two-item subtests for the five reasoning modes yielded reliability estimates ranging from 0.56 to 0.82.

Factor analysis of the data set by Tobin and Capie produced evidence of construct validity. A one-factor solution accounted for 43% of the common variance. Each subtest was highly correlated with this factor; factor structure loadings for the five modes of reasoning ranged from 0.60 to 0.72. A correlation of 0.80 between TOLT scores and Piagetian clinical interview results for 25 students was obtained, offering evidence of concurrent validity with the traditional but time-consuming interview technique.

Background Questionnaire

An eight-item questionnaire was distributed along with the Test of Logical Thinking (Appendix E). The purpose of this questionnaire was to gather data on sex, age, major, rank, and previous coursework so that any relationships between these attribute variables and the variables of importance in the study could be assessed.

Concept Map Scoring Procedures

Concept maps constructed by students in all three treatment groups were evaluated according to criteria adapted from those developed by Novak (1981; Novak and staff, 1981). Appendix A contains the Novak group's criteria. Assessed through this procedure are the number of correct and explicit relationships, degree of hierarchy, degree of branching, degree of general-to-specific organization, and number of cross links for a concept map.

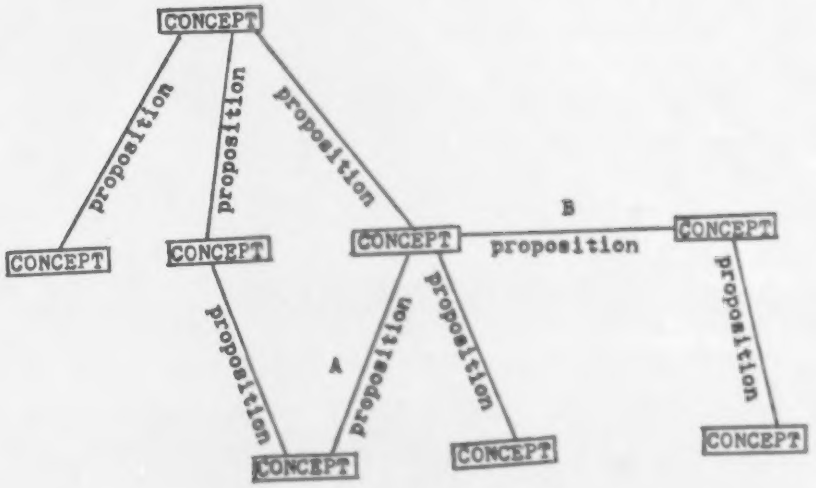
To test the inter-rater reliability of the procedure, Novak (Novak and staff, 1981) had five raters with varying backgrounds evaluate 18 different maps by applying the established criteria. An analysis of variance showed no significant rater differences on concept map scores ($\underline{F} = 1.20$; $p < 0.32$).

A preliminary examination of the concept maps produced by students in this study suggested three modifications to the Novak group's criteria. First, Novak's guidelines call for counting only the relationships that are correctly and explicitly labeled by a propositional phrase written on the lines connecting concepts. The rationale is that concept links must be accurate and specific if they are to have any meaning for learners. Unlabeled or incorrectly labeled relationships on a concept map indicate either arbitrary associations between concepts or misconceptions; neither facilitates learning. While Novak's procedure applies the correct-and-explicit test to the "relationships" scoring category only, the researcher decided that this test should apply *all* scoring criteria because of the rationale stated above.

A second modification to Novak's concept map scoring procedure involved the "general to specific" scoring category. A given concept on a concept map should be more general than concepts appearing below it and more specific than concepts located above it. Under the Novak guidelines, a person evaluating a map's general-to-specific organization examines each conceptual relationship on the map and decides if the higher concept is more general than the lower concept. From zero to five points are awarded to a map, depending on the percentage of relationships arranged in the proper (i.e., general to specific) direction.

Making this evaluation is not difficult when students construct concept maps from a short reading assignment. (This is the research procedure used in the Novak group's studies). However in this research project, students in NR 201 were directed to review lecture notes, handouts, and text chapters in order to make their concept maps. The concepts a person considers "more general" and those rated "more specific" would seem, in this case, to vary greatly with the student's existing knowledge and with the sources of that person's information (textbook, handouts and/or notes). The researcher found the general to specific category difficult to evaluate because of such ambiguities. Therefore, this criterion was not considered in final data analyses.

The third change in the criteria related to the "cross links" category. Cross links are connections between different branches of a concept map. Both relationship A and relationship B in Figure 3 are cross links. Often cross links form closed loops in a map (e.g., relationship A in Figure 3); this feature facilitates the counting of cross links in complex concept maps. Since cross links join together separate sections of a concept map, their presence indicates that the student has mentally integrated different groups of the cluser of concepts under consideration.


CONCEPT
proposition
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B
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A
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CONCEPT
CONCEPT
CONCEPT

Figure 3: Examples of Cross Links in a Concept Map

Novak's procedure involves awarding one point for each cross link present. Given the complexity of the concepts mapped in the three NR 201 concept mapping assignments, any cross link represents a significant conceptual connection. Thus, the researcher decided that awarding two points for each cross link would better weight the important integrating function that cross links reflect.

Since hierarchical concept maps and propositional concept maps lack some features found in the hierarchical-propositional concept maps for which Novak's group developed their scoring procedure, map features not part of these strategies could not be evaluated. The finalized concept map scording procedures adopted for this study are summarized in Table 2 and appear in full in Appendix F. In Appendix G are examples of student-constructed concept maps and how they were scored.

Natural Resources Concepts Posttest

This instrument was a 24-item multiple-choice test designed by the writer to assess students' understanding of concepts presented in NR 201. It was a part of the regular course final examination, which consisted of 100 multiple-choice items. See Appendix H. Students used answer sheets that were machine scored.

Proposed posttest items were submitted to a panel of five Ohio State University faculty members in natural resources and science education. Their suggestions were utilized in developing the final instrument.

Table 2

Comparison of Concept Map Scoring Procedures

Scoring Criterion	Concept Mapping Procedures		
	HP	H	P
1. Relationships	1 point per correct relationship	1 point per relationship	1 point per correct relationship
2. Hierarchy	1 point per level[a]	1 point per level[a]	(not considered)
3. Branching	1 point for 1st branching; 3 points for each additional branching[b]	1 point for 1st branching; 3 points for each additional branching	1 point for 1st branching; 3 points for each additional branching[b]
4. Cross Links	2 points per correct cross link	2 points per cross link	2 points per correct cross link
Total Score	1 + 2 + 3 + 4	1 + 2 + 3 + 4	1 + 2 + 3 + 4

[a] Up until 2 levels beyond last branching if map remains linear.

[b] Relationships in branches must be correct.

Test questions were written so that the 24-item posttest could be divided into two sets of subscales for analysis. Half of the test items represented information that should have been present on the concept maps that students constructed. The other half of the test items required knowledge related to the assigned concept maps but not directly represented on them. This scheme resulted in two 12-item subscales: 1) Mapped Concepts, and 2) Unmapped Concepts.

Each Natural Resources Concepts Posttest item was also classified according to topics of the three assigned concept maps. A third of the questions related to energy resources, while another third of the questions addressed wildlife ecology and the remaining items dealt with resource economics. Three eight-item subscales were thus produced.

Test forms were machine scored and analyzed by the Item Analysis Program developed and maintained by the Office of Testing at The Ohio State University. Separate keys were used to obtain scores for each subscale.

Presented in Table 3 are summary statistics and a reliability estimate for each posttest subscale, for the entire posttest, and for the complete 100-item NR 201 final examination. The Kuder-Richardson 20 reliability statistic is an estimate of the internal consistency of a test instrument. Since this measure increases in size with the homogeneity of the test, the relatively low KR-20's for some subscales indicate that the test questions comprising these subscales are comparatively heterogeneous.

Table 3

Summary Statistics and KR-20 Reliability
for the Natural Resources Concepts Posttest,
Posttest Subscales and the NR 201 Final Examination

Test	# of Items	Mean Score	Standard Deviation	KR-20 Reliability
Natural Resources Concepts Posttest	24	17.4	2.9	0.59
Mapped Concepts Subscale	12	9.5	1.8	0.44
Unmapped Concepts Subscale	12	8.2	1.8	0.45
Energy Resources Subscale	8	6.2	1.0	0.03
Wildlife Ecology Subscale	8	6.5	1.3	0.39
Resource Economics Subscale	8	5.1	1.8	0.62
NR 201 Final Examination	100[a]	74.8	7.9	0.78

[a] 24 items on this test comprised the Natural Resources Concepts Posttest

Concept Mapping Attitude Assessment

This instrument permitted the assessment of student attitudes toward several aspects of concept maps and the concept mapping strategy. The Concept Mapping Attitude Assessment contained 10 Likert-type items and 4 open-ended questions. Appendix J contains a copy of the instrument. The items had originally been developed and evaluated during the pilot study.

Students filled out the assessment after handing in the NR 201 final examination. A KR-20 of 0.81 was obtained as a measure of this instrument's internal consistency. This figure indicates that items in the Concept Mapping Attitude Assessment are relatively homogeneous; i.e., they tend to measure the same construct.

Procedures

The study involved several tasks that were carried out according to the timetable shown in Table 4. The researcher visited the class approximately every other week to make announcements and monitor the distribution and collection of assignments. Close contact was maintained with the instructor and teaching assistant, and these individuals cooperated in the data collection process.

Students were informed that a study was being conducted to evaluate various methods of learning natural resources concepts in order to improve instruction in NR 201. The students were asked

Table 4

Timetable for Research Tasks

Date	Research Task
9/25	Preassessment of Background Knowledge administered; TOLT and Background Questionnaire assigned; research project described to NR 201 students
9/29	TOLT and Background Questionnaire due
10/1 to 10/7	Panel review of Preassessment and the concept mapping instructional modules
10/13	Students assigned to treatment groups; Concept Mapping Workbooks distributed
10/15	Concept mapping instructional module assigned
10/15 to 10/27	Concept mapping instructional modules available to students
10/22	Concept Map #1 (Energy Resources) assigned
10/27	Assignment Sheet from concept mapping instructional module due
10/29	Concept Map #1 due; Concept Map #2 (Wildlife Ecology) assigned
11/5	Concept Map #2 due
11/10	Concept Map #3 (Resource Economics) assigned
11/17	Concept Map #3 due
11/25 to 11/30	Panel review of Natural Resources Concepts Posttest and Concept Mapping Attitude Assessment
12/7	Posttest and Attitude Assessment administered

to assist the researcher by using only materials assigned to their treatment group and not discussing concept maps with students in other groups.

In order to determine whether the three modules conveyed their respective concept mapping strategies accurately, a two-part validation study was conducted. A panel consisting of seven Ohio State University faculty members in science education and environmental education examined the preliminary scripts and workbooks. Each panelist was asked to read the scripts, complete the workbook exercises as directed in the scripts, and then fill out a brief questionnaire. This questionnaire requested that panel members identify the features a concept map should have according to each of the three sets of module materials. Panelists were also asked to comment on the content and organization of the slide-tape program scripts and accompanying workbooks. The questionnaire appears in Appendix K.

All seven panel members correctly identified the features that each type of concept map should possess. Many of their suggestions regarding workbooks and scripts were incorporated into the final version of the concept mapping instructional modules.

Students in the target population supplied data for the second part of the validation study. Each concept mapping workbook (see Appendix C) included an assignment sheet which the students filled out and handed in after completing the slide-tape module. Information provided on the sheet enabled the researcher to assess the degree to which a student understood the basic characteristics of the concept mapping strategy assigned to his or her treatment group. Results of this assessment appear in Table 5. It can be seen from these data that virtually all students correctly identified the appropriate concept map features.

Table 5

Students' Understanding of
Concept Map Characteristics
After Completing the Instructional Module

Concept Map Characteristic	Concept Mapping Groups		
	Group 1 H-P	Group 2 H	Group 3 P
1. Hierarchy	36 (97.3%)	40 (100%)	N/A[b]
2. Linking lines between concepts	37 (100%)	40 100%)	37 (100%)
3. Labels on linking lines	36 (97.3%)	N/A[a]	37 (100%)

[a] Hierarchical maps do not include labels on linking lines.

[b] Propositional concept maps do not include a hierarchical organization.

The assignment sheet also permitted the researcher to determine whether students had actually listened to the slide-tape program and completed the workbook exercises. Three students failed to hand in their assignment sheet, even though the sheet counted as a writing assignment for NR 201. These students were eliminated from subsequent data analyses.

Assignment of concept maps and the administration of the various tests were carried out as described above under Instrumentation and Treatments.

Data were keypunched and analyzed through computer programs contained in the Statistical Package for the Social Sciences (SPSS). The SPSS programs used included FREQUENCIES, PEARSON CORR, REGRESSION, CANCORR, MANOVA, and RELIABILITY. In addition, the Natural Resources Concepts Posttest scores were compiled and analyzed by the Item Analysis Program developed and maintained by the Office of Testing at The Ohio State University. Results of these analyses appear in Chapter IV.

CHAPTER IV

ANALYSIS OF RESULTS

Overview

The empirical data are presented and analyzed in this chapter. An explanation of treatment group mortality and checks on treatment group equality are followed by tests of hypotheses related to Subproblem 1, Subproblem 2 and Subproblem 3 of the study.

A 0.05 level of significance was used for all statistical tests unless otherwise stated. In this chapter all hypotheses are stated in the null form.

Treatment Group Mortality

Initially 132 students were registered for Natural Resources 201. These students were first separated into a high prior knowledge block and a low prior knowledge block based upon their scores on the Preassessment of Background Knowledge. This resulted in 66 students per prior knowledge group. Within each of these groups, students were randomly assigned to one of three concept mapping treatment groups, which meant 44 students per treatment or 22 students per cell.

Two students accidentally received concept mapping workbooks intended for other treatment groups. It was decided to allow these students to remain in their new groups and count their scores as part of their new groups' data.[1]

During the quarter, 9 students (6.8% of the original 132) dropped NR 201. Graduating seniors were given the option of not taking the final examination, and 2 (1.6% of the remaining 123 students) decided to exercise that option. In addition, 7 students (5.8% of the remaining 121 students) did not turn in one or more of the required concept mapping assignments.

Of the initial 132 NR 201 registrants, therefore, complete data were obtained from 114. As Table 6 shows this mortality was rather evenly distributed among treatment groups and prior knowledge blocks. Thus, differential mortality among cells in the research design is not of concern when interpreting the findings of this study.

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[1] One student was in the high prior knowledge/treatment group 1 cell and completed treatment group 2's module. The other student was in the low prior knowledge/treatment group 3 cell and completed treatment group 1's module. This explains the minor initial cell size differences depicted in Table 6.

Table 6

Mortality in Treatment Groups and Blocking Groups

Prior Knowledge Groups	Concept Mapping Groups			Row Totals
	Group 1: HP	Group 2: H	Group 3: P	
High	21[a] 4 17	23 3 20	22 3 19	66 10 56
Low	23 3 20	22 2 20	21 3 18	66 8 58
Column Totals	44 7 37	45 5 40	43 6 37	132 18 114

[a] Key: original group size/mortality/final group size

Treatment Group Equality

Students were randomly assigned to three treatment groups. Although random assignment should theoretically produce statistically equivalent treatment groups, differences in abilities or background could exist among groups because of sampling error.

To test for treatment group equality, separate one-way analyses of variance were performed with treatment groups as the independent variable in each analysis. The following measures were used as dependent variables: pretest score, TOLT score, number of biology credits, number of natural resources credits, number of social science credits, number of other credits related to Natural Resources 201, and total number of related credits.

Results of these tests appear in Table 37, Appendix L. Significant effects were found for number of biology credits ($p < 0.005$) and total number of credits ($p < 0.01$) while the number of other related credits approached significance ($p < 0.06$). No other effects were statistically significant.

To identify which of these three variables should later be used as covariates, multiple regressions were performed with biology credits, other credits and total credits as predictors of membership in each treatment group. The multiple regression data in Table 38, Appendix L indicates that the number of biology credits accounts for a significant portion of the variability in treatment group membership. Additional variance accounted for by the other two variables was comparatively minor. Therefore, it was decided to use number of biology credits as a single covariate in any subsequent analysis where effects of treatment group membership are assessed.

Analysis of Subproblem 1 Data

This part of the research project examined the relationship of two cognitive characteristics to student performance on subsequent concept mapping assignments.

The two characteristics studied were existing knowledge of natural resources concepts, as measured by the Preassessment of Background Knowledge, and level of cognitive development, as measured by the Test of Logical Thinking (TOLT). Also treated as independent variables were scores on the five TOLT subscales which are intended to represent five logical reasoning processes: propositional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning.

Performance on each concept mapping task (assignment) was broken down by the four concept map evaluation criteria; i.e., number of relationships, number of hierarchical levels, degree of branching, and number of cross links. The total concept map score (the sum of the four evaluation ratings) and the time taken by the students to complete each map were also considered as dependent variables in the analysis of Subproblem 1 data.

Since the study involved three different treatments, and since three different concept mapping tasks were assigned, the performances of each treatment group on each assignment were analyzed separately. Means and standard deviations for the variables in Subproblem 1 appear in Table 7. Following this table, each hypothesis is considered separately.

Table 7

Treatment Group Means and Standard Deviations on Preassessment of Background Knowledge, TOLT, and Concept Map Performance

	Concept Mapping Treatment Groups					
	Group 1: HP		Group 2: H		Group 3: P	
VARIABLES	MEANS	S.D.'s	MEANS	S.D.'s	MEANS	S.D.'s
Pretest	18.92	2.84	18.64	3.60	19.25	3.63
TOLT	6.16	2.82	7.06	2.39	7.19	2.58
Proposit.	1.26	0.89	1.64	0.72	1.34	0.84
Control.	1.11	0.93	1.25	0.87	1.61	0.73
Probab.	1.32	0.84	1.33	0.79	1.42	0.77
Correl.	1.32	0.81	1.56	0.73	1.42	0.77
Combin.	1.16	0.82	1.28	0.81	1.36	0.76
Map 1 Rel.	10.18	5.95	16.11	1.82	11.75	5.34
Map 1 Hier.	4.68	1.07	4.83	1.13	-	-
Map 1 Branch.	6.76	5.21	10.58	4.17	8.08	4.69
Map 1 Cross	1.47	2.01	3.17	3.15	1.28	1.86
Map 1 Total	23.11	11.70	34.69	6.44	21.11	10.30
Map 1 Time	30.71	18.87	27.36	20.65	42.44	29.37
Map 2 Rel.	11.71	6.25	18.28	2.97	13.25	4.81
Map 2 Hier.	5.74	1.60	5.33	1.10	-	-
Map 2 Branch.	7.50	4.84	11.17	3.38	9.53	4.49
Map 2 Cross	4.37	5.32	9.00	5.52	2.94	3.08
Map 2 Total	29.32	15.05	43.78	9.47	25.72	10.83
Map 2 Time	44.61	23.31	40.00	26.13	44.58	23.34

Table 7 (Continued)

	Concept Mapping Treatment Groups					
	Group 1: HP		Group 2: H		Group 3: P	
VARIABLES	MEANS	S.D.'s	MEANS	S.D.'s	MEANS	S.D.'s
Map 3 Rel.	11.08	6.58	19.14	3.74	13.28	5.42
Map 3 Hier.	5.74	1.24	5.52	1.48	-	-
Map 3 Branch.	7.13	6.17	14.00	3.99	8.42	4.60
Map 3 Cross	3.26	4.54	8.83	6.65	3.06	3.72
Map 3 Total	27.21	15.82	47.50	12.53	24.75	12.14
Map 3 Time	42.50	22.26	41.94	26.47	50.14	21.89

Relationship between Prior Knowledge and Concept Mapping

Pearson correlation coefficients were calculated in order to test the relationship between scores on the Preassessment of Background Knowledge and concept mapping task scores. The following hypothesis was tested:

H_1: There will be no significant correlation between students' prior knowledge and their scores on concept mapping tasks.

Correlation coefficients appear in Table 8.

Data presented in Table 8 reveal that of the four concept map evaluation criteria (relationships, hierarchy, branching, and cross links) only one, branching, had a significant relationship to prior knowledge. This relationship occurred only once out of nine times: for performance by subjects in treatment group 2 (H) on concept map 1. With this single exception, hypothesis 1 cannot be rejected at the 0.05 significance level.

Although time-on-task was not a direct part of H_1, it could have been used together with the concept map evaluation criteria in a multiple regression. Therefore, correlation coefficients for time-on-task were calculated and are presented in Table 8. The negative direction of the correlations is not surprising; it indicates that students who scored higher on the Preassessment of Background Knowledge tended to take less time to complete certain concept mapping assignments.

Table 8

Correlations between Prior Knowledge and Concept Mapping Performance, by Concept Map and Treatment Group

Concept Map Subscores	Concept Mapping Treatment Groups								
	Group 1: HP			Group 2: H			Group 3: P		
	Map 1	Map 2	Map 3	Map 1	Map 2	Map 3	Map 1	Map 2	Map 3
Relationships	-0.04	-0.05	0.12	0.16	-0.16	0.06	0.02	-0.03	-0.04
Hierarchy	0.03	0.05	0.18	-0.12	0.17	0.00	-	-	-
Branching	0.09	-0.04	0.02	0.27*	0.18	-0.10	0.12	-0.07	0.04
Cross Links	-0.19	0.05	0.17	0.13	-0.18	0.05	-0.10	-0.02	0.19
Total	-0.01	-0.01	0.12	0.25	-0.07	0.01	0.05	-0.05	0.05
Time	-0.14	-0.14	-0.13	-0.44**	-0.38**	-0.40**	-0.44**	-0.23	-0.28*

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Since the majority of the correlations related to hypothesis 1 were not statistically significant, no further analysis of these results was attempted.

Relationship between Cognitive Development and Concept Mapping

To examine the relationship between level of cognitive development (as measured by TOLT) and performance on concept mapping tasks, Pearson correlation coefficients were computed. Hypothesis 2 was tested.

> H_2: There will be no significant correlation between students' level of cognitive development and their scores on concept mapping tasks.

Correlation coefficients are listed in Table 9.

Among the four concept mapping subscores, branching had the greatest number of significant correlations with TOLT score; three correlations were significant at the 0.05 level. Of the nine correlations with branching, all but one were in the positive direction. Hierarchy correlated with TOLT twice -- once positively and once negatively. Two significant positive correlations with TOLT were found for total concept map score, while relationships and time-on-task had one significant correlation each. In these nine instances, hypothesis 2 is rejected. The hypothesis cannot be rejected for the remaining relationships between TOLT and concept mapping performance variables.

Table 9

Correlations between Cognitive Development and Concept Mapping Performance, by Concept Map and Treatment Group

Concept Map Subscores	Concept Mapping Treatment Groups								
	Group 1: HP			Group 2: H			Group 3: P		
	Map 1	Map 2	Map 3	Map 1	Map 2	Map 3	Map 1	Map 2	Map 3
Relationships	0.21	0.06	0.25	0.08	0.10	0.15	-0.21	0.18	0.28*
Hierarchy	-0.37*	-0.17	0.07	0.07	0.26*	-0.19	-	-	-
Branching	0.32*	-0.11	0.17	0.50***	0.14	0.43**	0.14	0.17	0.27
Cross Links	-0.22	-0.22	0.22	-0.02	0.11	0.04	-0.21	0.08	0.23
Total	0.17	-0.11	0.24	0.31*	0.18	0.19	-0.09	0.17	0.30*
Time	0.34*	0.03	0.07	-0.22	-0.25	-0.11	-0.19	-0.02	-0.08

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Cognitive development, as indicated in Table 9, was found to be a significant predictor of three variables for subjects in treatment group 1 (HP) on concept map 1. To investigate this association further a multiple regression was carried out. Multiple regression is a statistical procedure through which the relationship between one variable and a set of other variables may be analyzed. This technique identifies the linear combination of a group of variables that best explains or predicts another variable. In addition, the effects of one variable may be partialled out (adjusted for) before examining the effect of other variables.

The multiple regression performed in connection with H_2 was conducted to portray the relationship of cognitive development (as measured by the TOLT) to concept map characteristics (i.e., scores on the four evaluation criteria). The correlation between TOLT and time-on-task was partialled out first before entering scores on the four concept map evaluation criteria into the regression. Results of this analysis are contained in Table 10.

Inspection of the R-squared column in Table 10 reveals that while time-on-task accounted for 11.8% of the variability in TOLT scores, the addition of hierarchy, cross links, and relationships to the regression added 14.4%, 5.4%, and 4.0%, respectively, to the R-squared value for the multiple regression equation. Branching, which by itself correlated 0.32 with TOLT (see Table 9 and the simple-r column of Table 10), improved the explanatory power

Table 10

Multiple Regression Summary Table for TOLT as a Predictor of Concept Map Performance for Treatment Group 1 on Concept Map 1

VARIABLES	R SQUARED	RSQ. CHANGE	SIMPLE R	B	BETA
Time	0.12	0.12	0.34	0.42	0.28
Hierarchy	0.26	0.14	-0.37	-0.81	-0.31
Cross Links	0.32	0.05	-0.22	-0.49	-0.35
Relationships	0.36	0.04	0.21	0.69	0.15
Branching	0.36	0.00	0.32	0.71	0.13
(Constant)				8.18	

of the regression equation by less than 1%. Nearly all the variability in the TOLT that was related to branching, therefore, was already accounted for by the variables entered earlier into the multiple regression equation.

The relationship of TOLT to the concept map variables may be compared by studying the standardized regression coefficients or beta weights for each variable. These coefficients appear in the multiple regression summary table column entitled "beta" and their magnitudes are in standard deviation units[2]. Table 10 shows that the beta weights for time-on-task, hierarchy, and cross links are similar and roughly twice as high as coefficients for the other two concept map variables. Thus, the concept map performance scores most strongly predicted by TOLT are hierarchy and cross links; TOLT predicts time-on-task nearly equally well.

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[2] The standardized regression coefficient for branching, for example, may be interpreted as follows: for each standard deviation unit increase in branching score, the explained TOLT score increases by 0.13 standard deviation units.

It should be noted, however, that the relationship of both hierarchy and cross links to TOLT is negative, which means that students in the HP group with higher TOLT scores tended to construct concept map 1 with fewer hierarchical levels and fewer cross links than did students who scored lower on the TOLT. Simple correlation coefficients in Table 9 show that the relationship of TOLT to hierarchy and cross links could be positive or negative, depending upon the treatment group and concept mapping assignment.

No other multiple regressions were run because other significant correlations listed in Table 9 involved only one of the four concept mapping subscores.

Relationship between Logical Reasoning Processes and Concept Mapping

The TOLT consists of five two-item subscales designed to evaluate logical reasoning processes that are believed to contribute to cognitive development. These processes are: propositional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning.

Pearson correlation coefficients between each TOLT subscale and each concept map characteristic were calculated in order to explore the associations between these sets of variables. The hypothesis below was tested.

H_3: There will be no significant correlations between logical reasoning processes and scores on concept mapping tasks.

Presented in Table 11 are the correlation coefficients.

Some patterns in the Table 11 data are evident. There were no significant correlations between logical reasoning processes (i.e., TOLT subscale scores) and concept map performance variables for students in the P group on concept map 2, and only a few scattered significant relationships for this group on concept maps 1 and 3 were found. In contrast, correlation coefficients were significant at the 0.05 level in six instances[3] for the H-P group on both map 1 and map 2. Nine out of these 12 associations, however, were negative. Four significant correlations were found for the H group 2 on both map 1 and map 3.

The concept map subscores that correlated more frequently with logical reasoning processes were branching (10 times), cross links (6 times), and hierarchy (5 times). Eight of the nine significant correlations which involved branching were positive, whereas all five of the significant correlations involving hierarchy were negative. The nonsignificant correlations generally supported these trends. Therefore, students with higher scores on the particular TOLT subscale tended to construct maps with more branching but fewer hierarchical levels. For cross links, the pattern is less clear because positive and negative correlations are represented nearly equally.

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[3] when only the four concept map evaluation criteria are counted.

Positive and negative correlations also seem to balance out for time-on-task and total concept map score. The only apparent exceptions are the total scores on map 3 where all correlations, including two that are significant at the 0.05 level, are positive. Students with higher TOLT subscale scores tended to construct better maps for the third concept mapping assignment. However, the correlation coefficients are -- except in two instances -- not significant.

Thus for the 34 statistically significant associations found, H_3 is rejected. The hypothesis is not rejected for the remaining relationships.

To put the results into perspective, it should be pointed out that 270 correlations were tested for hypothesis 3. Of these 270, 236 (87.4%) were found not to be statistically significant. Since these 270 tests were conducted on the same sample of students, the probability is relatively high that 12.6% of the correlations would turn out to be significant at the 0.05 level due to chance alone (Kennedy, 1978, p. 82). Inspection of Table 11 reveals that if a more conservative alpha level of 0.01 was employed, only six pairs of variables would be significantly related. No relationships would be statistically significant at the 0.001 level.

Table 11

Correlations between Logical Reasoning and
Concept Map Performance, by
Treatment Group and Concept Map

Logical Reasoning Processes	Concept Map Subscore: Relationships								
	Concept Map 1			Concept Map 2			Concept Map 3		
	HP	H	P	HP	H	P	HP	H	P
Proposit.	0.28*	-0.05	-0.22	0.13	0.24	0.18	0.08	0.11	0.19
Control.	0.04	0.33*	-0.17	-0.03	-0.10	0.03	0.32*	0.09	0.16
Probab.	0.22	-0.05	0.07	0.21	0.24	0.16	0.22	0.06	0.13
Correl.	-0.06	-0.16	-0.27	-0.30*	0.04	0.08	0.01	0.25	0.24
Combin.	0.21	0.12	-0.13	0.17	-0.07	0.17	0.19	-0.23	0.24

	Concept Map Subscore: Hierarchy								
	Concept Map 1			Concept Map 2			Concept Map 3		
	HP	H	P	HP	H	P	HP	H	P
Proposit.	-0.22	0.05	-	-0.27*	0.22	-	0.20	-0.18	-
Control.	-0.40**	0.12	-	-0.05	0.02	-	0.14	-0.24	-
Probab.	-0.37	-0.06	-	-0.06	0.26	-	-0.25	0.18	-
Correl.	-0.06	0.08	-	0.00	0.23	-	0.08	-0.05	0
Combin.	-0.25	0.02	-	-0.30*	0.11	-	0.04	-0.31*	-

Table 11 (Continued)

	Concept Map Subscore: Branching								
	Concept Map 1			Concept Map 2			Concept Map 3		
	HP	H	P	HP	H	P	HP	H	P
Proposit.	0.31*	0.35*	0.02	0.01	0.18	0.21	0.03	0.35*	0.24
Control.	0.23	0.41**	0.07	-0.10	0.09	0.16	0.19	0.21	0.21
Probab.	0.18	0.18	0.28*	-0.01	0.11	0.08	0.14	0.40**	0.05
Correl.	0.02	0.22	-0.02	-0.33*	-0.07	0.08	-0.03	0.20	0.07
Combin.	0.31*	0.41**	0.13	0.05	0.10	0.03	0.22	0.21	0.36*

	Concept Map Subscore: Cross Links								
	Concept Map 1			Concept Map 2			Concept Map 3		
	HP	H	P	HP	H	P	HP	H	P
Proposit.	-0.16	-0.11	-0.26	-0.14	0.20	0.04	0.00	-0.01	0.19
Control.	-0.38**	0.10	-0.17	-0.36*	-0.06	-0.10	0.15	-0.02	0.23
Probab.	-0.06	0.03	0.10	0.17	0.22	0.10	0.29*	-0.07	0.01
Correl.	0.04	-0.03	-0.35*	-0.29*	-0.02	0.11	0.20	0.28*	0.08
Combin.	-0.14	-0.08	-0.02	-0.09	0.04	0.10	0.09	-0.02	0.27

Table 11 (Continued)

	Total Concept Map Score								
	Concept Map 1			Concept Map 2			Concept Map 3		
	HP	H	P	HP	H	P	HP	H	P
Proposit.	0.23	0.14	-0.16	-0.02	0.28*	0.18	0.06	0.12	0.23
Control.	0.02	0.41**	-0.09	-0.18	-0.03	0.05	0.26	0.06	0.22
Probab.	0.15	0.09	0.18	0.15	0.27	0.13	0.21	0.13	0.08
Correl.	-0.01	0.07	-0.22	-0.33*	0.00	0.10	0.05	0.28*	0.16
Combin.	0.20	0.24	-0.01	0.03	0.05	0.11	0.19	0.01	0.33*

	Time-on-Task								
	Concept Map 1			Concept Map 2			Concept Map 3		
	HP	H	P	HP	H	P	HP	H	P
Proposit.	0.36*	-0.22	0.05	0.13	-0.23	0.11	0.10	-0.16	0.13
Control.	0.12	-0.17	-0.17	0.08	-0.19	-0.11	0.03	-0.08	-0.18
Probab.	0.26	-0.20	-0.31*	-0.04	-0.22	-0.21	0.06	-0.21	-0.37*
Correl.	0.09	-0.24	0.03	-0.14	-0.29*	0.20	-0.05	-0.15	0.10
Combin.	0.29*	0.12	-0.26	0.05	0.15	-0.08	0.07	0.25	0.00

*$p < 0.05$
**$p < 0.01$
***$p < 0.001$

Multiple regression analysis would reduce the number of statistical tests and potentially provide more information about the relationships among variables studied in connection with hypothesis 3. However, if the canonical correlation analysis procedure was used, the same number of relationships could be collapsed into even fewer tests. Canonical correlation is a multivariate technique which performs an analysis of the relationship between one _set_ of variables and another _set_ of variables. Linear combinations from each variable set that are most highly correlated with each other are identified. The resulting canonical variates account for the maximum amount of relatedness between the two sets of variables entered into the analysis (Nie, _et al_., 1975).

Since students were assigned to three treatment groups and each student constructed three concept maps, nine canonical analyses were performed. In each analysis, the two variable sets studied were five TOLT subscales and the four concept map subscores.

Significant canonical variates were found in only two of nine canonical analyses: for treatment group 1 on concept map 1, and for the same students on concept map 2. The lack of significant canonical relationships elsewhere suggests that linear combinations of TOLT subscale scores and the four concept map subscores are not significantly related in these seven instances. In other words, the overall variability in the five logical reasoning processes does not appear to significantly predict the overall variability in concept map subscores for either treatment group 2 or treatment group 3.

Results of the canonical analysis for the HP group on concept map 1 appear in Table 13. Table 13 presents data for the HP group's performance on the second concept mapping assignment. In interpreting a canonical correlation summary table, primary attention is paid to those variables with standardized coefficients larger than or equal to an absolute value of 0.50. The greater the standardized coefficient, the more important the original variable is in forming the canonical variate.

The significant correlation of 0.78 in Table 12 means that the canonical variate for the set of logical reasoning variables correlates 60.8% with the corresponding canonical variate for the set of concept mapping performance variables. Standardized coefficients for the original variables indicate that controlling variables and correlational reasoning bear the greatest relationship to the canonical variate for the logical reasoning processes. Similarly, among the concept mapping variables cross links, hierarchy, and relationships have the strongest associations with their group's canonical variate. The negative sign of the coefficient for controlling variables suggests that this variable is negatively related to the canonical variate, whereas the positive signs of the other logical reasoning coefficients indicates positive relationships. Since the signs for the two most important concept mapping characteristics (i.e., cross links and hierarchy) are positive, these variables are positively related to their canonical variates and to correlational reasoning. Their association with controlling variables, however, is negative.

Table 12

Canonical Correlation Summary Table for Hypothesis 3
Treatment Group 1, Concept Map 1

Number	Canonical Correlation	Chi-Square	D.F.	Significance
1	0.78	37.44	20	0.010
2	0.38	7.68	12	0.810

Standardized Coefficients for Logical Reasoning Processes

	CANVAR 1
Proposit.	-0.15
Control.	-0.64
Probab.	-0.37
Correl.	0.53
Combin.	-0.38

Standardized Coefficients for Concept Mapping Performance

	CANVAR 1
Relationships	-0.50
Hierarchy	0.55
Branching	-0.20
Cross Links	0.74

Table 13

Canonical Correlation Summary Table for Hypothesis 3
Treatment Group 1, Concept Map 2

Number	Canonical Correlation	Chi-Square	D.F.	Significance
1	0.61	33.82	20	0.027
2	0.56	18.78	13	0.094

Standardized Coefficients for Logical Reasoning Processes

	CANVAR 1
Proposit.	-0.41
Control.	-0.42
Probab.	-0.02
Correl.	0.49
Combin.	-0.57

Standardized Coefficients for Concept Mapping Performance

	CANVAR 1
Relationships	-1.56
Hierarchy	0.36
Branching	0.42
Cross Links	1.05

The canonical correlations for concept map 2 are summarized in Table 13. In this case, combinatorial reasoning is the single TOLT variable to have a standardized coefficient greater than 0.50, while among the concept map criteria cross links and relationships are the variables of most importance. It should also be noted that the standardized coefficients for cross links and relationships have different signs; this suggests that their influence upon the canonical variate for the set of concept mapping variables is in opposite directions.

In Tables 12 and 13, there appears to be a similarity in the standardized regression coefficients for logical reasoning processes. Correlational reasoning is positively related to the canonical variate for logical reasoning processes, while the remaining four reasoning processes exhibit negative associations with their canonical variate. To determine whether this pattern is consistent for all three of the HP group's concept maps, the canonical correlation analysis for concept map 3 was re-examined. Summary data appear in Table 14.

Table 14

Canonical Correlation Summary Table for Hypothesis 3:
Treatment Group 1, Concept Map 3

Number	Canonical Correlation	Chi-Square	D.F.	Significance
1	0.47	15.61	15	0.41[a]
2	0.41	7.33	8	0.50

Standardized Regression Coefficients for Logical Reasoning Processes		Standardized Regression Coefficients for Logical Reasoning Processes	
Proposit.	-0.11	Relationships	-0.99
Control.	-0.58	Hierarchy	-
Probab.	0.27	Branching	-0.47
Correl.	0.88	Cross Links	1.29
Combin.	-0.45		

[a] No canonical correlations are significant at $p < 0.05$

As reported above, no canonical correlations for the HP group on map 3 are significant. However, the signs of the standardized regression coefficients are identical to those for maps 1 and 2, except that probabilistic reasoning has a positive sign in map 3 but a negative sign in map 2.

In summary, the most frequent pattern of relationships was no relationship between logical reasoning and concept mapping performance. Simple correlations and canonical analyses revealed a comparatively small number of significant relationships, but the variables involved and sometimes the direction of the relationships varied from treatment group to treatment group and from concept mapping assignment to concept mapping assignment. The most apparent and consistent results were 1) positive relationships between branching and the five logical reasoning processes, and 2) negative relationships between hierarchy and logical reasoning.

Analysis of Subproblem 2 Data

In this portion of the study, the relationship of prior knowledge and cognitive development to student achievement on the concepts posttest was investigated. Since learners in the three treatment groups approached concept mapping with three different strategies, the performances of each treatment group were analyzed separately.

The independent variables for all hypotheses in Subproblem 2 were the same as those in Subproblem 1. That is, prior knowledge of natural resources concepts was evaluated through the Preassessment of Background Knowledge, and the TOLT was used to assess level of cognitive development. Logical reasoning processes -- as measured by the five TOLT subscales -- were again treated as a set of independent variables.

Scores on the Natural Resources Concepts Posttest constituted the dependent variable for hypotheses considered in Subproblem 2. As explained in Chapter III, the posttest was designed so that it could be divided into two sets of subscales for analysis: 1) mapped concepts vs. unmapped concepts, and 2) energy concepts vs. ecology concepts vs. economics concepts. (Energy, ecology, and economics were the subjects of concept map 1, concept map 2, and concept map 3, respectively). Most statistical tests related to Subproblem 2, therefore, were performed first upon the entire Natural Resources Concepts Posttest and then upon each set of subscales.

Means and standard deviations for the variables in Subproblem 2 appear in Table 15.

Relationship between Prior Knowledge and Achievement

To analyze the relationship between scores on the Preassessment of Background Knowledge and scores on the Natural Resources Concepts Posttest, Pearson correlation coefficients were computed. The following hypothesis was tested:

> H_4: There will be no significant correlation between students' prior knowledge and their achievement on the posttest.

Correlations related to this hypothesis are shown in Table 16.

Table 16 reveals that, for each treatment group, prior knowledge was a significant predictor of two of six achievement measures.[4] The complete 24-item Natural Resources Concepts Posttest was related to prior knowledge held by students in the H and P concept mapping groups. For the remaining treatment group, prior knowledge correlated significantly with the mapped concepts and unmapped concepts subscales which together comprise the Natural Resources Concepts Posttest. (The correlation coefficient for prior knowledge and the entire posttest for treatment group 1 approached significance, $p < 0.61$).

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[4] When the posttest and all its subscales are each considered as separate measures of achievement

Table 15

Treatment Group Means and Standard Deviations on Preassessment of Background Knowledge, TOLT, and the Natural Resources Concepts Posttest

	Concept Mapping Treatment Groups					
	HP		H		P	
VARIABLES	MEANS	S.D.'s	MEANS	S.D.'s	MEANS	S.D.'s
Pretest	18.84	2.83	18.93	3.58	19.38	3.66
TOLT	6.11	2.85	7.03	2.54	7.05	2.69
Proposit.	1.60	0.74	1.24	0.89	1.35	0.85
Control.	1.28	0.88	1.08	0.92	1.59	0.72
Probab.	1.35	0.80	1.30	0.85	1.41	0.76
Correl.	1.53	0.75	1.30	0.81	1.38	0.79
Combin.	1.26	0.78	1.19	0.81	1.32	0.78
Posttest	18.10	2.59	17.11	3.31	18.30	2.79
Mapped	9.38	1.75	9.43	1.86	9.92	1.53
Unmapped	8.73	1.68	7.81	1.91	8.38	1.69
Energy	6.15	0.98	6.05	1.18	6.30	1.00
Ecology	6.73	1.13	6.19	1.43	6.68	1.14
Economics	5.15	1.67	4.86	1.92	5.32	1.90

Table 16

Correlations between Prior Knowledge
and Achievement, by Treatment Group

Achievement Measure	Concept Mapping Treatment Groups		
	Group 1: HP	Group 2: H	Group 3: P
Mapped Concepts	0.31*	0.21	0.24
Unmapped Concepts	0.28*	0.24	0.29*
Energy Concepts	0.19	0.43**	0.18
Ecology Concepts	0.21	0.22	0.23
Economics Concepts	0.17	-0.01	0.22
Complete Posttest	0.26	0.29*	0.31*

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

On the basis of these findings, H_4 may be rejected at the 0.05 level for the significant relationships listed in Table 15. Prior knowledge and posttest score -- or a breakdown of the posttest by subscales -- exhibited a significant positive association for all three treatment groups.

According to learning theories discussed in Chapter II, prior knowledge ("what the learner already knows," to borrow Ausubel's phrase) and cognitive development are related to achievement. Which cognitive characteristic explains more of the variability in learning? If posttest scores are statistically adjusted for the effects of one of these variables, how strongly will the second variable correlate with achievement? These questions suggest multiple regression analysis on posttest scores with both TOLT and prior knowledge as predictor variables. Since hypothesis 5 deals with the association between cognitive development and the Natural Resources Concepts Posttest, the multiple regressions will be discussed in connection with H_5.

Relationship between Cognitive Development and Achievement

In order to investigate the relationship between level of cognitive development and achievement on the Natural Resources Concepts Posttest, Pearson correlation coefficients were calculated. Hypothesis 5 was tested.

H_5: There will be no significant correlation between students' level of cognitive development and their achievement on the posttest.

Table 17 presents correlation coefficients that relate to this hypothesis.

The disparity in these results is pronounced. For HP concept mappers, TOLT score explains performance on the Natural Resources Concepts Posttest and all five of the posttest subscales. In contrast, Table 17 includes no significant TOLT-posttest correlations for the P group and only one significant relationship for the performance of learners in the H group. All but one of the correlation coefficients in Table 17 are positive.

Hypothesis 5 is rejected for the HP group, but it cannot be rejected for students in the H group (except on the energy concepts subtest) or the P group.

As mentioned in connection with the preceeding hypothesis, multiple regression analyses of posttest scores could help distinguish the variability accounted for by prior knowledge from that explained by cognitive development. One analysis was run for each concept mapping treatment group. Results appear in Table 18.

The figures in Table 18's R-squared columns indicate that for each treatment group a single cognitive characteristic accounted for most of the variability in posttest scores. Once the effects of that first variable were removed, the remaining variable contributed only slightly to the explanatory power of the regression equation. While the better predictor of the HP group's performance

Table 17

Correlations between Cognitive Development and Achievement, by Treatment Group

Posttest Subscale	Concept Mapping Treatment Groups		
	Group 1: HP	Group 2: H	Group 3: P
Mapped Concepts	0.34*	0.21	0.09
Unmapped Concepts	0.44**	0.14	0.25
Energy Concepts	0.31*	0.28*	0.11
Ecology Concepts	0.48***	0.24	0.02
Economics Concepts	0.32*	-0.02	0.23
Complete Posttest	0.51***	0.23	0.20

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Table 18

Multiple Regression Summary Tables
for Prior Knowledge and Cognitive Development
as Predictors of Posttest Achievement

Treatment Group 1: Hierarchical-Propositional Concept Mapping					
Variable	R Squared	RSQ Change	Simple R	B	Beta
TOLT	0.26	0.26	0.51	0.55	0.47
Prescore	0.28	0.02	0.26	0.18	0.16
(Constant)				10.28	
Treatment Group 2: Hierarchical Concept Mapping					
Variable	R Squared	RSQ Change	Simple R	B	Beta
Prescore	0.09	0.09	0.29	0.18	0.25
TOLT	0.11	0.02	0.23	0.17	0.16
(Constant)				13.56	
Treatment Group 3: Propositional Concept Mapping					
Variable	R Squared	RSQ Change	Simple R	B	Beta
Prescore	0.10	0.10	0.31	0.21	0.27
TOLT	0.11	0.01	0.20	0.11	0.11
(Constant)				13.47	

on the posttest was TOLT score, the posttest scores of subjects in groups 2 and 3 were better explained by prior knowledge. The difference in stardardized regression coefficients (beta weights) for the two variables are largest for the HP and P groups, reflecting the predominance of a single cognitive variable as a predictor of achievement in these instances.

Thus, the measure which explains more of the variability in learning depends, according to these findings, upon the treatment group: prior knowledge gets the nod over TOLT for two of three groups.

Relationship between Logical Reasoning Processes and Achievement

Pearson correlation coefficients between each TOLT subscale and the posttest and its subscales were calculated in order to probe the relationships between these sets of variables. The hypothesis below was tested.

> H_6: There will be no significant correlation between any logical reasoning process and student achievement on the posttest.

Compiled in Table 19 are the correlation coefficients related to H_6.

Examination of Table 19 reveals that three of the five reasoning processes -- controlling variables, probabilistic reasoning, and correlational reasoning -- are significantly related to at least three posttest measures for the hierarchical-propositional

Table 19

Correlations between Logical Reasoning Processes and Achievement, by Treatment Group

Achievement Measures	Concept Mapping Treatment Group 1: HP				
	Proposit.	Control.	Probab.	Correl.	Combinat.
Mapped Concepts	0.20	0.22	0.30*	0.28*	0.11
Unmapped Concepts	0.16	0.62***	0.26	0.25	0.15
Energy Concepts	0.36*	0.35*	-0.04	0.19	0.16
Ecology Concepts	0.09	0.35*	0.60**	0.43**	0.14
Economics Concepts	0.03	0.45**	0.16	0.21	0.16
Complete Posttest	0.22	0.53**	0.34*	0.37*	0.21

Table 19 (Continued)

	Concept Mapping Treatmeng Group 2: H				
	Proposit.	Control.	Probab.	Correl.	Combinat.
Mapped Concepts	0.14	-0.07	0.12	0.22	0.30*
Unmapped Concepts	-0.01	0.21	0.15	-0.13	0.20
Energy Concepts	0.16	0.01	0.16	0.38**	0.21
Ecology Concepts	0.14	0.26	-0.03	-0.04	0.43**
Economics Concepts	-0.07	-0.08	0.17	-0.13	0.05
Complete Posttest	0.09	0.09	0.18	0.06	0.33*

Table 19 (Continued)

	Concept Mapping Treatment Group 3: P				
	Proposit.	Control.	Probab.	Correl.	Combinat.
Mapped Concepts	0.06	-0.08	0.12	-0.04	0.23
Unmapped Concepts	0.19	0.13	0.27	0.04	0.24
Energy Concepts	-0.09	0.06	0.17	0.06	0.19
Ecology Concepts	0.26	-0.16	-0.07	-0.14	0.12
Economics Concepts	0.12	0.12	0.29*	0.05	0.23
Complete Posttest	0.15	0.03	0.23	0.00	0.27

$^{*}p < 0.05$
$^{**}p < 0.01$
$^{***}p < 0.001$

concept mapping group. Associations between controlling variables and achievement for learners in the HP group are significant at the 0.05 level for all posttest scales except for mapped concepts; three of these correlations are significant at the 0.01 level. The remaining set of significant correlations is between combinatorial reasoning and the achievement of the H group. Hypothesis 6 can be rejected in these instances.

Aside from combinatorial reasoning, data in Table 19 suggest that there is little relationship between logical reasoning and the H group's posttest scores. The lack of association is even more clear-cut for the P group. For only one out of 30 possible pairs of variables is there a significant correlation, and this relationship is not significant at the more conservative 0.01 level. For the H group and the P group (with the exception of combinatorial reasoning), H_5 cannot be rejected.

Since the Pearson correlation coefficients indicated that for treatment group 1 (HP) there were significant relationships between logical reasoning and achievement, two canonical correlation analyses were performed to explore these associations further. The five logical reasoning processes were used as the first data set in each analysis of the treatment group 1 data. One canonical analysis involved the mapped concepts subscale and the unmapped concepts subscale as the second data set; the other canonical analysis employed the subscales related to energy, ecology and economics concepts as the second data set. Results of these multivariate analyses appear in Table 20 and Table 21.

Table 20

Canonical Correlation Summary Table for Treatment Group 1: Logical Reasoning Processes Correlated with Mapped and Unmapped Concepts Posttest Subscales

Number	Canonical Correlation	Chi-Square	D.F.	Significance
1	0.68	23.86	10	0.008
2	0.33	3.75	4	0.441

Standardized Coefficients for Logical Reasoning Processes

	CANVAR 1
Proposit.	-0.31
Control.	1.02
Probab.	0.31
Correl.	0.15
Combin.	-0.14

Standardized Coefficients for Posttest Subscales

	CANVAR 1
Mapped	-0.03
Unmapped	1.03

Table 21

Canonical Correlation Summary Table for Treatment Group 1: Logical Reasoning Processes Correlated with Energy, Ecology and Economics Concepts Posttest Subscales

Number	Canonical Correlation	Chi-Square	D.F.	Significance
1	0.78	40.86	15	0.000
2	0.48	10.95	8	0.204

Standardized Coefficients for Logical Reasoning Processes

	CANVAR 1
Proposit.	-0.47
Control.	0.40
Probab.	0.81
Correl.	0.47
Combin.	-0.08

Standardized Coefficients for Posttest Subscales

	CANVAR 1
Energy	-0.17
Ecology	0.96
Economics	0.13

Standardized coefficients for the variable sets entered into the first canonical analysis (Table 20) indicate that controlling variables exhibits the only important correlation (i.e., its standardized coefficient is greater than 0.50) with the canonical variate for the set of logical reasoning processes. Similarly, of the posttest subscales only the unmapped concepts scale is strongly related to the canonical variate for its data set. Considering that the simple correlation between controlling variables and scores on the unmapped concepts subscale was a highly significant 0.62, the results of this canonical analysis are not surprising. Thus, the substantive relationship between logical reasoning and achievement is between controlling variables and unmapped concepts in this case.

The canonical correlations contained in Table 21 uncover a different pattern. Again, only one logical reasoning process and one posttest subscale bear important relationships to their respective canonical variates. In this case probabilistic reasoning and achievement on the ecology concepts subscale exhibit a relationship.

To summarize the findings for Hypothesis 6, the association between logical reasoning and posttest achievement reduces to two pairs of related variables for the HP group: controlling variables and unmapped concepts, and probabilistic reasoning and ecology concepts. The relationships for the H and P groups were not strong enough or numerous enough to warrant the rejection of Hypothesis 6 for these groups.

Analysis of Subproblem 3 Data

This part of the investigation involved a comparison of the three concept mapping procedures. As in Subproblem 1, performance on each concept mapping assignment was broken down by the four concept map evaluation criteria; total concept map score and time-on-task were also considered in the analyses.

Scores on the Natural Resources Concepts Posttest and its subscales constituted one set of dependent variables. Another dependent variable was attitude toward concept mapping, which was evaluated through the Concept Mapping Attitude Assessment.

Student Mastery of Concept Mapping

Did students in Natural Resources 201 construct concept maps which adequately and accurately reflected the relationships among the concepts they were asked to map? The following hypothesis was tested in connection with this question:

H_7: The mean concept map score for the final (third) map which students construct will not meet an 80% mastery level for any of the treatment groups.

This hypothesis required that a criterion map or "master" map be developed for each concept mapping technique. Since three concept mapping strategies were compared in the study and three concept maps were assigned, a total of nine master maps were necessary.

Initial master maps were developed by the researcher after an examination of text readings, handouts, and lecture notes which related to each assignment. These maps and relevant course materials were submitted to a panel of four natural resources and science education faculty members for their evaluation and comments. Input from the panel was used to generate the final master maps, which appear in Appendix M.

Each master map was evaluated according to the concept map scoring procedures described in Chapter III. Students' concepts maps were then assessed for adequacy by dividing their raw concept map scores into the master map scores and multiplying the result by 100. This converted students' raw scores[5] into percentages of master map scores. Table 22 presents the converted scores.

Because the concept mapping scoring procedures varied among the three treatments (see Table 2 in Chapter III), data in Table 22 are not numerically comparable. General trends can be noted, however.

It seems that students in all three groups tended to have the most difficulty constructing cross links. In most cases, branching in the maps was more adequate than cross links while mean percentage scores for relationships generally exceeded those for the branching category. Hierarchy (which did not apply to the

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[5] Raw scores were used as dependent variables for Subproblem 1 and as independent variables for hypotheses 8 through 12 in Subproblem 3. Hypothesis 7 is the only situation which involves the conversion of raw scores to percentages.

Table 22

Mean Raw Scores and Mean Percentage Scores for Concept Mapping Performance, by Treatment Groups

Concept Mapping Scores	Concept Mapping Treatment Groups								
	Group 1: HP			Group 2: H			Group 3: P		
	Map 1	Map 2	Map 3	Map 1	Map 2	Map 3	Map 1	Map 2	Map 3
Relationships	10.2 56.7%	11.7 55.7%	11.1 55.5%	16.2 90.0%	18.1 86.2%	18.9 94.5%	11.9 66.1%	13.2 62.9%	12.9 64.5%
Hierarchy	4.7 117.5%	5.7 190.0%	5.7 114.0%	4.7 117.5%	5.3 176.7%	5.6 112.0%	- -	- -	- -
Branching	6.7 51.5%	7.5 57.7%	7.1 32.0%	10.7 82.3%	11.3 86.9%	63.2 13.9 63.2%	8.0 50.0%	9.4 72.3%	8.2 37.3%
Cross Links	1.5 25.0%	4.4 31.4%	3.2 32.0%	3.2 53.3%	8.6 61.4%	8.4 84.0%	1.4 23.3%	2.9 20.7%	3.0 30.0%
Total Score	23.1 56.3%	29.3 57.4%	27.2 47.7%	34.9 85.1%	43.4 85.1%	46.7 81.9%	21.3 53.3%	25.6 53.3%	24.1 46.3%

propositional concept maps) garnered the highest mean scores, exceeding 100% in all instances. These trends apparently reflect a propensity for learners to construct maps with more hierarchical levels than the master maps, but fewer relationships, branches and cross links.

The change in average total scores from concept map 1 to concept map 2 to concept map 3 followed a similar pattern in all three treatment groups. The first and second assignments were virtually identical in terms of overall adequacy as measured by percent of total master map score; however, there was a drop in the mean total score on the third concept map.

Although data in Table 22 suggest that H_7 cannot be rejected for treatment groups 1 and 3 while it can be rejected for group 2, this writer is hesitant to make such distinctions among the concept mapping procedures. Hierarchical maps were scored more leniently than the other two types of maps because the accuracy of propositional relationships depicted on the map is not considered in evaluating the relationships, branching, and cross links of hierarchical concept maps. Therefore, a hierarchical-propositional or propositional concept map which receives a percentage total score of 50% may be equal in meaningfulness and/or adequacy to a hierarchical map which earns an 80% score. In regard to hypothesis 7, then, no judgement will be made.

Relationship between Concept Mapping and Achievement

To analyze the relationship between concept mapping task scores on the Natural Resources Concepts Posttest, Pearson correlation coefficients were computed. The following three hypotheses were tested:

H_8: There will be no significant correlation between scores on concept mapping tasks and achievement on the concepts posttest for students in the treatment group exposed to the hierarchical-propositional concept mapping approach.

H_9: There will be no significant correlation between scores on concept mapping tasks and achievement on the concepts posttest for students in the treatment group exposed to the hierarchical concept mapping approach.

H_{10}: There will be no significant correlation between scores on concept mapping tasks and achievement on the concepts posttest for students in the treatment group exposed to the propositional concept mapping approach.

Correlation materials for these variables appear in Table 23.

Some patterns in the HP group data are evident. Table 23 shows that for concept maps 1 and 3, four concept mapping scores are related to several measures of achievement. Only hierarchy does not correlate significantly with the posttest or any of its subscales. In only one of a possible 30 correlations does a significant relationship exist between concept map 2 subscores and achievement.

Table 23

Correlation Coefficients for Concept Mapping
Performance and Achievement, by Treatment Group and Concept Map

Achievement Measures	Concept Map Subscore: Relationships								
	Concept Map 1			Concept Map 2			Concept Map 3		
	HP	H	P	HP	H	P	HP	H	P
Mapped Concepts	0.39**	-0.31*	0.15	0.11	-0.05	0.04	0.41**	0.06	0.43**
Unmapped Concepts	0.02	0.23	0.19	-0.14	0.17	0.11	0.23	-0.03	0.17
Energy Concepts	0.11	-0.06	0.15	-0.18	0.02	-0.12	0.08	0.14	0.24
Ecology Concepts	0.02	0.04	0.03	-0.11	-0.04	-0.02	0.18	-0.13	-0.03
Economics Concepts	0.27	-0.08	0.20	0.02	0.11	0.20	0.43**	0.08	0.39**
Complete Posttest	0.20	-0.06	0.2[illegible]	-0.10	0.08	0.09	0.36*	0.02	0.34*

	Concept Map Subscore: Hierarchy								
	Concept Map 1			Concept Map 2			Concept Map 3		
	HP	H	P	HP	H	P	HP	H	P
Mapped Concepts	-0.15	-0.35*	-	-0.15	0.12	-	-0.02	-0.09	-
Unmapped Concepts	-0.23	0.01	-	0.01	-0.10	-	0.05	0.45**	-
Energy Concepts	-0.18	-0.27*	-	-0.15	0.21	-	0.03	0.06	-
Ecology Concepts	-0.17	-0.09	-	0.25	-0.23	-	-0.05	0.10	-
Economics Concepts	-0.16	-0.15	-	-0.10	-0.05	-	0.08	0.27*	-
Complete Posttest	-0.23	-0.23	-	0.00	0.01	-	0.04	0.23	-

Table 23 (Continued)

	Concept Map Subscore: Branching								
	Concept Map 1			Concept Map 2			Concept Map 3		
	HP	H	P	HP	H	P	HP	H	P
Mapped Concepts	0.32*	0.28*	0.29*	0.05	0.27*	-0.07	0.40**	0.11	0.32*
Unmapped Concepts	0.09	0.19	0.41**	-0.19	0.29*	0.18	0.16	0.07	0.31*
Energy Concepts	0.17	0.15	0.28*	-0.20	0.21	-0.11	0.17	-0.01	0.33*
Ecology Concepts	0.09	0.31*	-0.03	-0.31*	0.25	-0.17	0.05	0.00	-0.03
Economics Concepts	0.23	0.09	0.47**	0.00	0.26	0.27	0.34**	0.17	0.38*
Complete Posttest	0.23	0.31*	-0.41**	-0.21	0.37*	0.07	0.28*	0.12	0.36*

	Concept Map Subscore: Cross Links								
	Concept Map 1			Concept Map 2			Concept Map 3		
	HP	H	P	HP	H	P	HP	H	P
Mapped Concepts	0.15	-0.41*	-0.07	0.19	-0.06	0.07	0.33*	0.02	0.47**
Unmapped Concepts	-0.41**	0.18	-0.16	-0.27	0.12	0.03	0.19	-0.15	0.28*
Energy Concepts	-0.27	-0.06	-0.02	-0.15	-0.06	-0.18	0.09	0.08	0.22
Ecology Concepts	-0.14	-0.07	0.08	-0.14	0.04	0.12	0.21	-0.12	0.14
Economics Concepts	0.05	-0.14	-0.24	-0.07	0.03	0.00	0.29*	-0.06	0.43**
Complete Posttest	-0.12	-0.16	-0.14	-0.16	0.03	-0.02	0.29*	-0.09	0.43**

Table 23 (Continued)

	Total Concept Map Score								
	Concept Map 1			Concept Map 2			Concept Map 3		
	HP	H	P	HP	H	P	HP	H	P
Mapped Concepts	0.35*	-0.19	0.20	0.11	0.06	-0.03	0.42**	0.05	0.45**
Unmapped Concepts	-0.04	0.27*	0.25	-0.22	0.21	0.13	0.22	-0.01	0.28*
Energy Concepts	0.07	-0.01	0.20	-0.21	0.07	-0.15	0.13	0.09	0.30*
Ecology Concepts	0.01	0.14	0.02	-0.17	0.08	-0.04	0.15	-0.09	0.02
Economics Concepts	0.23	-0.07	0.27	-0.03	0.14	0.20	0.40**	0.08	0.45**
Complete Posttest	0.16	0.05	0.26	-0.16	0.18	0.06	0.34*	0.03	0.42**

$*p < .05$
$**p < .01$
$***p < .001$

The only frequent correlations of significance for the H group are for concept map 1. Few relationships are apparent for hierarchical concept maps 2 and 3.

The distribution of significant correlational relationships for propositional concept mapping is reminiscent of that for hierarchical-propositional concept mapping. Concept map 3 shows the greatest number of associations, but the degree of branching in concept map 1 is a significant predictor of posttest score and four out of five posttest subscales.

Because several significant associations between concept mapping performance and achievement were indicated by the data in Table 23, ten canonical correlation analyses were run on posttest subscales to investigate these relationships further. The treatment groups and concept maps investigated were these:

1. Treatment Group 1, Concept Map 1;
2. Treatment Group 1, Concept Map 3;
3. Treatment Group 2, Concept Map 1;
4. Treatment Group 3, Concept Map 1;
5. Treatment Group 3, Concept Map 3.

For each treatment group and concept map studied, two canonical analyses were performed: one analysis with mapped vs. unmapped concepts in the second variable set, and one analysis with the energy, ecology and economics subscales in the second variable set. The four concept mapping subscales constituted the first variable set for all ten analyses.

Significant canonical correlations were found for only two of the ten analyses. Results of these procedures are presented in Table 24 and Table 25.

Table 24

Canonical Correlation Summary Table
for Treatment Group 1, Concept Map 1:
Concept Mapping Subscores Correlated with
Mapped and Unmapped Concepts Posttest Subscales

Number	Canonical Correlation	Chi-Square	D.F.	Significance
1	0.57	18.91	8	0.015
2	0.41	5.93	3	0.115

Standardized Coefficients for Concept Mapping Subscales	CANVAR 1
Relationships	-0.05
Hierarchy	-0.15
Branching	0.11
Cross Links	-0.97

Standardized Coefficients for Posttest Subscales	CANVAR 1
Mapped	-0.72
Unmapped	1.12

Table 25

Canonical Correlation Summary Table
for Treatment Group 3, Concept Map 3
Concept Mapping Subscores Correlated with
Mapped and Unmapped Concepts Posttest Subscales

Number	Canonical Correlation	Chi-Square	D.F.	Significance
1	0.50	13.96	6	0.030
2	0.36	4.56	2	0.103

Table 25 (Continued)

Standardized Coefficients for Concept Mapping Subscales	CANVAR1	Standardized Coefficients for Posttest Subscales	CANVAR 1
Relationships	0.51	Mapped	1.02
Branching	-0.13	Unmapped	-0.03
Cross Links	0.67		

Data in Table 24 reveal that the overall relationship between concept map subscores and posttest subscales is between cross links and both mapped and unmapped concepts. Cross links is positively correlated with mapped concepts but negatively correlated with unmapped concepts.

Relationships and cross links appear to be the important concept map subscores in Table 25, and they are positively correlated to scores on the mapped concepts subscale. These are the substantive associations between concept mapping and achievement for treatment group 3, concept map 3.

Thus, for hypotheses 8 through 10, canonical correlation analysis was able to summarize the many significant correlations shown in Table 23 in only two instances. In order to identify the other pairs of variables for which H_8 or H_{10} is rejected, it is necessary to refer to the simple correlation coefficients.

For the HP group's concept map 3, the total concept map score and all subscores except hierarchy appear to be related to the overall posttest score and the mapped concepts and economics concepts subscales. In the same treatment group there seems to be virtually no significant relationship between performance on concept map 2 and posttest achievement. Besides the canonical relationship found in Table 30, the relationships, branching, and total scores on concept map 1 are significantly associated with the mapped concepts subscale.

Far fewer relationships exist for hierarchical concept maps and achievement. In concept map 1, all four concept map features appear to be associated with the mapped concepts subscale. Aside from the additional individual correlations, no other comprehensive patterns of relationship are evident.

For propositional concept mapping, the degree of branching in concept map 1 is correlated with the complete posttest and all but one subscale. No associations exist for concept map 2. All concept mapping criteria in concept map 3 are positively related to the posttest and its subscales for mapped concepts and economics concepts.

Effects of Prior Knowledge and Concept Mapping Treatment upon Achievement

A major objective of this study was to compare the effects of the concept mapping procedures upon student achievement. Included in the research design were three levels of concept mapping treatment: hierarchical-propositional concept mapping, hierarchical concept mapping and propositional concept mapping. Also built into the design was a blocking variable, prior knowledge, which had two levels -- high and low. Achievement was assessed through the 24-item Natural Resources Concepts Posttest.

An analysis of initial treatment group differences revealed that the number of biology credits taken prior to NR 201 differed significantly among students assigned to the three treatment groups. Therefore, it was decided to use number of biology credits as a covariate in analysis of variance tests.

This design was developed to test the two hypotheses listed below.

H_{11}: There will be no significant difference in posttest scores between students with high prior knowledge and students with low prior knowledge.

H_{12}: There will be no significant difference in posttest scores among the three concept mapping treatment groups.

An analysis of covariance (ANCOVA) was performed with treatment group and prior knowledge as independent variables, posttest score as the dependent variable, and biology credits as a covariate. Cell means and standard deviations appear in Table 26. Table 27 displays results of the ANCOVA.

Examination of Table 26 shows that students in the low prior knowledge block had lower posttest scores than did students in the higher prior knowledge block for all three treatment groups. The significant $\underline{F}$ ratio for prior knowledge, $\underline{F}$ (1,107) = 11.22, $p < .001$, in Table 27 indicates that students who began NR 201 with a greater knowledge of natural resources concepts performed

Table 26

Cell Means and Standard Deviations for Posttest Score, by Concept Mapping Treatment Group and Prior Knowledge Block

Treatment Groups	Prior Knowledge Blocks: High Means	High S.D.'s	Low Means	Low S.D.'s
HP	18.19	3.15	16.29	3.27
H	19.00	2.47	17.20	2.44
P	19.15	2.60	17.29	2.73

Table 27

Analysis of Covariance Summary Table for Posttest Score, by Concept Mapping Treatment Group and Prior Knowledge Block

Source	D.F.	Mean Square	F	Significance
Treatment Group (A)	2	10.19	1.32	0.27
Prior Knowledge (B)	1	86.56	11.22	0.00
A X B	2	0.07	0.01	0.99
Residual	107	7.71		

significantly better on the Natural Resources Concepts Posttest than did students with lower entry-level knowledge. Hypothesis 11 can be rejected.

Although students in the HP group had lower posttest scores than did learners in the other two groups, this difference did not prove to be significant, $\underline{F}$ (2,107) = 1.32, $p < .271$. On the basis of this finding, H_{12} cannot be rejected. The analysis revealed no significant effect of concept mapping treatment upon achievement on the posttest.

In connection with hypothesis 12, the relationship between time-on-task and posttest score was also examined. Results are presented in Table 28.

As the correlation coefficients in Table 28 show, time-on-task did not explain a significant portion of the variability in posttest scores. Had any significant associations been found, an ANVOCA could have been run with one or more time-on-task variables as covariates in an attempt to uncover significant differences between treatment groups on the posttest.

Table 28

Correlations between Time-on-Task and Posttest Score, by Treatment Group and Concept Mapping Assignment

Concept Maps	Concept Mapping Treatment Groups Group 1: HP	 Group 2: H	 Group 3: P
1	0.08	0.06	-0.18[a]
2	-0.09	0.13	-0.16
3	-0.02	0.07	0.02

[a] This correlation coefficient came the closest to being significant, $p < 0.15$

Attitudes toward Concept Mapping

The Concept Mapping Attitude Assessment (CMAA) permitted the evaluation of students' attitudes toward several aspects of concept maps and the concept mapping strategies. Appendix H contains a copy of the instrument.

Since a KR-20 internal consistency estimate of 0.81 was obtained, it was decided that scores on the ten questions could be summed to form a composite score. The Likert-type items were coded in such a way that a lower CMAA score indicated a more favorable attitude towards concept mapping.

Attitude scores of subjects in the three treatment groups were used as dependent variables in an ANCOVA to test the following hypothesis:

> H_{13}: There will be no significant difference in attitudes toward concept mapping among the three treatment groups.

Concept mapping group and prior knowledge were treated as independent variables, with biology credits as a covariate. Table 29 presents the cell means and standard deviations. The ANCOVA summary table is contained in Table 30.

Table 29 reveals no consistent pattern among the means for prior knowledge blocks, but subjects in the HP and the P concept mapping groups have lower mean CMAA scores than learners in the H group. However, as depicted in Table 30 the F ratio for treatment group effects was not significant at the 0.05 level, $F\ (2,91) = 2.46$, $p < .091$. Hypothesis 13 is not rejected.

Table 29

Cell Means and Standard Deviations for CMAA Score, by Concept Mapping Treatment Group and Prior Knowledge Block

Treatment Groups	Prior Knowledge Blocks			
	High		Low	
	Means	S.D.'s	Means	S.D.'s
HP	31.71	4.20	29.82	6.28
H	34.06	5.34	33.42	5.93
P	30.00	6.29	31.71	4.30

Table 30

Analysis of Covariance Summary Table for CMAA Score, by Concept Mapping Treatment and Prior Knowledge Block

Source	D.F.	Mean Square	F	Significance
Treatment Group (A)	2	74.71	2.46	0.09
Prior Knowledge (B)	1	0.28	0.01	0.92
A X B	2	29.61	0.97	0.38
Residual	91	30.39		

Two additional questions about concept mapping were included with the CMAA. Responses to these items were analyzed to test Hypothesis 14.

H_{14}: There will be no difference in the acceptance of concept mapping among the treatment groups.

Frequency and percentage tabulations appear in Table 31. On question 1, the highest percentage of favorable responses was given by the HP treatment group, while students in the P concept mapping group offered the fewest positive responses regarding the place of concept mapping in NR 201. A similar pattern existed for question 2 except that percentages for the H and HP groups were essentially equal. Although this simple comparison of percents does not make use of formal statistical procedures, the positive responses of students in the hierarchical-propositional concept mapping group appear to indicate greater acceptance of this concept mapping technique. Within the limits of the analysis, H_{14} is rejected.

Table 31

Acceptance of Concept Mapping

Question 1:

Should concept mapping lessons and assignments be part of a course such as Natural Resources 201?__________

	Group 1: HP	Group 2: H	Group 3: P
No:	10 (34.5%)	15 (42.9%)	13 (54.2%)
Yes:	19 (65.5%)	20 (57.1%)	11 (45.8%)
Blank:	8	5	13

Question 2:

In all honesty, was participating in the concept mapping program worth your time?_________

	Group 1: HP	Group 2: H	Group 3: P
No:	16 (53.3%)	19 (52.8%)	20 (74.1%)
Yes:	14 (46.7%)	17 (47.2%)	7 (25.9%)
Blank:	7	4	10

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of Findings

The central purpose of this study was to investigate the relationship of concept mapping to selected cognitive characteristics and achievement measures. A secondary objective was to compare three versions of concept mapping.

Each student in an introductory college-level natural resources management course learned one of the concept mapping strategies and constructed three concept maps that dealt with course material. Cognitive development and prior knowledge related to natural resources were assessed at the beginning of the course, while achievement and attitudes toward concept mapping were measured at the course's conclusion.

Subproblem 1 involved an examination of the relationship of cognitive development and prior knowledge to student performance on concept mapping assignments. Virtually no significant relationships between prior knowledge and concept mapping were found, aside from time-on-task which correlated negatively with prior knowledge.

In a small number of instances, cognitive development (as measured by the TOLT) exhibited significant correlations with concept map performance. Branching had the greatest frequency of correlations -- three of a possible nine -- with TOLT score. Multiple regression analysis of the performance of the HP concept mappers on their first concept mapping task revealed that cross links and hierarchy were the concept map features most strongly predicted by TOLT scores. However, both correlations were in the negative direction.

The TOLT was then broken down into its five subscales, which represent five logical reasoning processes, to determine what associations existed between these specific thinking capabilities and concept mapping. The most frequent finding, especially for students in the H and P groups, was no relationship between logical reasoning and concept map scores.

Nevertheless, there were several statistically significant correlations discovered for the HP concept mapping group. Canonical analysis showed that controlling variables and correlational reasoning had the greatest relationship with the canonical variate for logical reasoning processes for concept map 1. Among the concept map variables cross links, hierarchy, and relationships had the most important associations with their canonical variate. While cross links, hierarchy and the logical reasoning process of correlational reasoning correlated positively with their respective canonical variates, relationships and controlling variables had negative correlationals with their canonical variates. For the performance of the hierarchical-propositional concept mappers on concept map 2, the canonical correlations exhibited a different pattern. Only one reasoning process, combinatorial reasoning, had a standardized coefficient greater than 0.50, while among the concept map variables cross links and relationships were the variables which most strongly related to their canonical variate. The coefficients for cross links and relationships had different signs, suggesting that their associations with the canonical variate for the set of concept mapping characteristics were in opposite directions.

In Subproblem 2, the relationship of prior knowledge and cognitive development to student achievement was investigated. Scores on the achievement posttest were broken down into two sets of subscales for analysis: 1) mapped vs. unmapped concepts, and 2) subscales for each of the three concept mapping assignments: energy, ecology and economics.

Significant positive relationships were found between prior knowledge and the posttest score -- and/or one or more posttest subscores -- for all three treatment groups. The same did not hold true for cognitive development. All six posttest measures correlated positively and significantly with TOLT for the HP group, but no significant relationship was found for the P group and only one significant correlation emerged for the H group.

Multiple regressions on posttest scores were performed for each treatment group in order to help distinguish the influence of prior knowledge from that of cognitive development. While the better predictor of treatment group 1's performance of the posttest was

TOLT score (r = 0.51), the posttest scores of subjects in groups 2 and 3 were better explained by prior knowledge (r = 0.29, r = 0.31, respectively). The differences in beta weights for the two variables were largest for treatment groups 1 and 3, reflecting the predominance of a single cognitive variable as a predictor of achievement in these instances.

The relationships of the five logical reasoning processes to achievement were examined in Subproblem 2 by correlating each TOLT subscale with the posttest and its subscales. Three of the five logical reasoning processes -- controlling variables, probabilistic reasoning and correlational reasoning -- were significantly related to at least three posttest measures for the HP group. Associations between controlling variables and achievement for learners in this group were significant at the p.05 level for all posttest scales except for mapped concepts; three of these correlations were significant at the more conservative 0.01 level. The remaining set of significant correlations was between combinatorial reasoning and the achievement of the H group. For only one of 30 possible pairs of variables was there a significant correlation between logical reasoning and achievement for learners in the P group. Canonical analysis for the HP group reduced the association between logical reasoning processes and posttest scores to two pairs of variables: controlling variables and unmapped concepts for concept map 1, and probabilistic reasoning and ecology concepts for concept map 2.

Subproblem 3 involved comparisons of the three concept mapping procedures: hierarchical-propositional concept mapping (HP), hierarchical concept mapping (H), and propositional concept mapping (P). Attempts were made to compare the strategies in terms of the adequacy of concept maps constructed, the relationship between concept mapping and achievement, the effects of prior knowledge and concept mapping treatment upon achievement, and students' attitudes towards concept mapping.

Students' concept maps were judged for adequacy by comparing them to master maps developed by the researcher and evaluated by a panel of college faculty members. In general, learners tended to construct maps with more hierarchical levels than the master maps but fewer relationships, branches and cross links. Since scoring procedures varied among the three concept mapping treatments, the adequacy of one type of map could not be compared with that of the other versions.

Correlation coefficients were computed to analyze the relationship between concept map scores and scores on the posttest. For the HP group's performance on concept map 3 the total concept map score and all subscores except hierarchy correlated significantly with the overall posttest score and the mapped concepts and economics concepts subscores. In the same treatment group there seemed to be no relationship with respect to concept map 2, but for concept map 1 the branching, relationships and total scores were significant predictors of scores on the mapped concepts subscale. Cross links, however, was found through canonical analysis to be negatively related to mapped concepts but positively related to the unmapped concepts posttest subscore.

In contrast, the only pattern of significant correlations that appeared to emerge for the H group was that all four concept map features were significantly correlated with the mapped concepts subscale.

For the P group, the degree of branching in concept map 1 was correlated with the complete posttest and all but one subscale. No associations existed for concept map 2. All concept map features in concept map 3 were positively related to the posttest and its subscales for mapped concepts and economics concepts.

To compare the effects of the three concept mapping strategies upon student achievement using an analysis of variance approach instead of the correlational statistics described above, an analysis of covariance was performed. The three levels of concept mapping and the two levels of prior knowledge were independent variables, while biology credits served as a covariate and achievement on the posttest was treated as the dependent variable. Although a significant effect for prior knowledge was found, there was no significant effect shown for concept mapping treatment, $\underline{F}\ (2,107) = 1.32$, $p < 0.271$. Thus, the effects of the three concept mapping procedures upon achievement, as measured in this study, were statistically equal. Time-on-task was not entered into the ANCOVA because no significant correlations were found between time variables and posttest scores.

An attitude scale, the Concept Mapping Attitide Assessment, was developed and found to have a high degree of internal consistency (KR-20 = 0.81). An analysis of covariance revealed no significant effect for treatment upon attitudes towards concept mapping. Responses to two additional questions, however, did indicate that students in the HP group expressed the most favorable attitudes toward the use of concept mapping and their participation in the concept mapping program. On both questions, learners in the P group gave the least favorable responses.

Discussion and Limitations of Findings

Subproblem 1

Aside from time-on-task, no significant relationships between prior knowledge and concept mapping were found. It appears, then, that the Preassessment of Background Knowledge and the concept mapping scoring procedures measured different aspects of cognitive structure. This result is consistent with the conclusions of Novak's group (Novak and staff, 1981); their study showed low or insignificant correlations between concept mapping skill and such variables as science grade, science final exam grade, and aptitude test scores.

Cognitive development also turned out to be a generally poor predictor of concept map scores, except that the TOLT significantly correlated with branching in three out of nine instances. Perhaps students with more developed mental abilities have more differentiated cognitive networks, as reflected by highly branched concept maps, but the existence of significance for only one-third of the correlations computed makes such a conclusion extremely tenuous.

Correlations between the TOLT subscales and concept mapping skill showed a similar pattern of non-significant coefficients. There were significant relationships found through two canonical analyses of data for the hierarchical concept mapping group, but the variables involved and even the directions of the relationships were so variable as to render an overall conclusion impossible. Logical reasoning processes appeared to have no consistent and statistically significant relationships with the concept mapping performance varibles.

With only about 40 students per treatment group, relationships which may exist between cognitive characteristics and concept mapping could have gone undetected. A larger sample size could have increased the likelihood of uncovering significant correlations.

On the other hand, the possibility of making an alpha error (i.e., stating that a significant relationship existed when it actually did not) was increased in this study by calculating multiple Pearson correlations on data drawn from the same sample. A more conservative level of significance -- 0.01, for example -- would have reduced the already low number of relationships found in Subproblem 1.

Subproblem 2

Meaningful learning theory holds that "what the learner already knows" is the most important influence upon subsequent learning. When the relationship of prior knowledge and cognitive development to posttest achievement were compared, prior knowledge was the better predictor for two of three concept mapping treatment groups. Only for learners in the HP group did TOLT score explain a greater percentage of the variability in posttest scores.

This writer is unable to develop a theoretical rationale for the HP group's results, and the literature offers few clues. Possibly the problem lies not in the theory but in the measurement of prior knowledge by the Preassessment of Background Knowledge. An instrument with greater content validity might produce results that would be more closely related to achievement on the posttest.

Logical reasoning processes showed a substantial number of correlations with posttest scores for the HP group only. The major consistent patterns in the performance of these students was the relationship of controlling variables, probabilistic reasoning and correlational reasoning to posttest measures. In particular, associations between correlational reasoning and achievement were the most numerous. Ability to recognize relationships among variables -- which is how Karplus (1979) defined correlational reasoning -- would seem to be a factor of some relevance to learning concepts. However, why was a significant correlation not found between achievement and propositional reasoning (the ability to make inferences from general statements)? From a theoretical standpoint, this ability would also appear to be related to concept learning. Limitations of the TOLT and its subscales,which were used to measure logical reasoning, are discussed below.

As in Subproblem 1, the small sample size probably masked some significant correlations among the variables investigated in Subproblem 2.

This writer must confess to a skepticism about the Test of Logical Thinking which has grown with his use and analysis of the instrument. The TOLT is intended to measure cognitive development and five of the logical reasoning processes thought to explain cognitive development. An examination of the ten items which comprise the instrument (see Appendix E) causes one to question whether the questions are actually assessing such abilities as propositional or correlational reasoning. The TOLT questions involve mathematics-related examples and abilities, while logical reasoning and cognitive development -- if they are valid constructs -- should apply to all disciplines. Indeed, this criticism might be leveled at most procedures, including clinical interviews, which attempt to evaluate cognitive development.

The TOLT items may be especially invalid as measures of cognitive abilities for students in Natural Resources 201. Many of these learners take an introductory statistics and probability course as part of their mathematics requirement during freshman year. Mathematical notions such as probability, proportionality and permutations are generally addressed in such courses, and a knowledge of these processes would probably be of great assistance to students taking the TOLT.

Subproblem 3

Comparisons of student-constructed concept maps with master map standards confirmed the findings of D. Townsend (1981) and Novak and staff (1981) that learners tend to make concept maps with relatively few branches and cross links. These concept map features were explicitly referred to in the slide-tape modules (see Appendix C). Apparently, even more emphasis was needed,or the cognitive structures of students simply did not contain relationships of the complexity portrayed by the master maps.

Novak and staff (1981) discovered no significant correlations between total concept map scores and their post-treatment conceptual exercises. In the present study, several frequent and significant sets of relationships were found, which suggested that at least in some instances concept mapping performance can predict achievement. An advantage in the design of this study was that correlations were run between posttest measures and subscores of the total concept map score. Greater insight into the relationship between concept mapping and achievement was provided by this breakdown of concept mapping into its four component characteristics.

It is noteworthy but not surprising that for two treatment groups (HP and P) performance on the economics concept map was significantly related to scores on the economics concepts subscale of the Natural Resources Concepts Posttest. In all three groups several concept map characteristics correlated higher and more often with the mapped concepts subscale than they did with the unmapped concepts subscale. Again, this finding is not surprising: it indicates that students scored higher on posttest questions that were more directly related to the concepts they mapped -- transfer of this learning to other concepts was less frequent.

Nearly all relationships between the concept map features and posttest achievement were positive. However, the frequent lack of significant correlations for cross links indicate that all trends were not equal or in the same direction. The finding that branching exhibited about a third more significant correlations with various posttest measures than did other aspects of concept maps suggests that branching may best reflect "what the learner knows."

Since concepts are held to be both hierarchical and propositional in nature, attempts by learners to integrate this understanding into their studies of ocncepts should facilitate learning. The researcher had anticipated, therefore, that the hierarchical-propostional concept mapping approach would have a significantly greater effect upon achievement than either the hierarchical or the propositional strategy. An analysis of covariance showed that such was not the case. No statistically significant differences were found for the treatments, although subjects in the high prior knowledge block significantly outscored learners in the low prior knowledge block on the posttest.

There are several possible explanations for this result. In the first place, the act of constructing concept maps with hierarchical levels and propostional relationships does not necessarily guarantee that students are "thinking hierarchically" or "thinking propositionally." Indeed the researcher found in scoring the concept maps that many hierarchical arrangements appreared puzzling (to him, at least) and many propositions written down by students were only marginally accurate or failed to express important ways in which concept pairs were related. Second, while it is true that learners were encouraged to study their concept maps in preparation for the final exam and posttest, several NR 201 students explained on the open-ended CMAA questions that they preferred other ways of learning. Thus concept maps were not the sole learning tools employed by subjects in the study.

Thirdly, students constructed only three maps, and they were not encouraged to discuss their maps with each other. Mean map scores for the HP and P groups did not reach the 80% mastery level, even on the final concept map. Thus, the differences between HP, H, and P mapping may not have been realized because most students had not completely mastered the technique.

And finally, differences in cognitive structure produced by the concept mapping treatments may not have been measured by the posttest since multiple-choice questions may require types of thinking quite different from those associated with concept mapping.

The Concept Mapping Attitude Assessment was unable to detect any differential effects that the three treatments may have had upon student attitudes toward concept mapping. Responses to the two supplementary questions did show that HP concept mappers were more favorable toward the value of concept mapping in NR 201 and their participation in the concept mapping project. If this finding is valid, it has a great deal of significance: none of the three strategies may produce better learning, but students find one technique more acceptable. If students refuse to try a new educational technique, no matter how effective it may be, the approach cannot influence learning.

Analyses in Subproblem 3 are subject to the same limitations of sample size and, for the correlations, multiple tests upon non-independent samples as the analyses in Subproblem 1. Alternate explanations for the findings related to the effects of treatment upon achievement are discussed above.

The two supplementary questions on the CMAA do not comprise test instruments for which reliability coefficients may be computed. Therefore, the finding that acceptance of concept mapping depended upon treatment group must be regarded with caution.

Final Conclusions

The cognitive characteristics of interest in this study -- prior knowledge, cognitive development, and logical reasoning -- did not show much relationship to students' concept mapping performance. Even though scores on three different concept mapping exercises were analyzed separately for each of the three treatment groups, no overall pattern in the data emerged. Concept mapping performance thus appears to be a different dimension of cognitive structure than the independent variables investigated in Subproblem 1.

When the relationships of prior knowledge and cognitive development to posttest achievement were compared, prior knowledge was the better predictor for two of the three concept mapping groups. This finding tends to support Ausubel's dictum that the "...most important single factor influencing learning is what the learner already knows." Yet the maximum percentage of variability in learning explained by these cognitive characteristics was in the neighborhood of 30%. Other factors must be examined to account for the remaining 70% of variability in achievement, including concepts students already knew before taking NR 201 that were not measured by the Preassessment of Background Knowledge.

Some logical reasoning processes, especially correlational reasoning, exhibited frequent significant correlations with the posttest. Although such a finding is logical, the lack of numerous correlations for propositional reasoning is puzzling. The limitations of the TOLT, discussed above, may be responsible for these inconsistent results.

Students in all three treatment groups were able to identify the essential features of concept mapping after listening to the slide-tape module and completing the workbook exercises. However, the maps constructed by the HP and P groups did not meet the 80% criterion of mastery. Individualized feedback which emphasizes the importance of branching, cross links, and relationships should have been provided to students in order to maximize the effectiveness of the treatments.

The breakdown of concept mapping into its four characteristics allowed the relationship of achievement to each characteristic to be explored. Numerous sets of correlations were found, especially when the following variables were involved: the HP group, map 1, map 3, branching, mapped concepts, and economics concepts. Concept mapping, in these instances, does predict learning.

Ausubel, Novak and Hanesian (1978) refer frequently to the notion of the progressive differentiation of concepts. They define this activity (p. 629) as a meaningful learning process "that results in further...elaboration of concepts or propositions in cognitive structure from the 'top downwards.'" It would seem that, of the four concept map characteristics, branching best represents progressive differentiation because branching is a measure of how well "tied together" higher-level concepts are to lower-level concepts. The finding in this study that branching was the best predictor of achievement supports the importance of progressive differentiation in subsequent concept learning.

The lack of a significant treatment effect upon posttest scores was unexpected. As explained above, differences among the three concept mapping procedures may not have been potent enough to produce differences in learning. The failure of most students to achieve 80% mastery on the mapping tasks suggests that learners may need more guidance and experience with concept mapping before any differences in achievement manifest themselves. In addition, the HP and H treatments may have been too similar. Both involved drawing lines between related concepts -- a task which is propositional, not hierarchical, in nature. This overlap may have resulted in such similar performances on the Natural Resources Concepts Posttest.

Responses to two individual questions indicated that the HP group expressed the most favorable attitudes toward concept mapping, but this difference disappeared when an ANCOVA was performed upon answers to the ten-item Concept Mapping Attitude Assessment. Thus, a conclusion that differences exist among attitudes towards concept mapping would be tenuous at best.

Recommendations

Further research on the effectiveness, implementation and limitations of concept mapping is needed. Findings of this study suggest several refinements and potential directions of inquiry.

1. Assessments of existing conceptual knowledge are needed. Multiple-choice instruments should be refined and validated, and more work needs to be done using concept maps as pre-assessments of cognitive structure (Champagne, et al., 1978).
2. Improved tests of specific mental reasoning abilities are needed. Pencil-and-paper instruments may be of only limited usefulness, but their convenience probably means that they will continue to see frequent application.
3. Relationships between concept map characteristics and achievement merit further exploration. This study has indicated that while some characteristics (especially branching) seem to be better predictors of achievement than others, the predictive power of a given concept map subscore varies with the topic mapped.
4. The Concept Mapping Attitude Assessment, developed in this study, has a high internal consistency. The instrument can probably be improved through a procedure such as FORTAP and then used to assess attitudes toward concept mapping in other settings.
5. The instructional modules developed for this project have been validated and can be the basis for other instructional efforts

and research. Individualized feedback on concept maps should be provided to help students improve their mapping skills.

6. Decisions and thought process which a student undergoes when making a concept map require more careful scrutiny than simply scoring the final map. Qualitative case studies of a few students and/or clinical interviews with a larger sample should provide insight into the ways in which students construct and use concept maps.
7. If multivariate techniques are to be employed to study variables that are related to concept mapping, the sample size must be considerably larger than that employed in this study.
8. The potency of the three versions of concept mapping may be improved by:
   a. providing more feedback to students (see #5, above);
   b. having students construct and discuss maps in small groups; and
   c. eliminating linking lines on hierarchical concept maps to make these maps less similar to the HP maps.
9. Posttests which relate more closely to the kinds of thought processes involved in concept mapping need to be developed.

In addition, concept mapping can be implemented in other ways besides having students make their own maps as was done in this study (Stewart, Van Kirk and Rowell, 1979; Bousquet, 1981). The problems investigated in this research and many of those suggested above also apply to alternate uses for concept mapping.

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APPENDIX A

REPORT OF THE PILOT STUDY

THE USE OF CONCEPT MAPS IN PROMOTING CONCEPT LEARNING IN A COLLEGE-LEVEL INTRODUCTORY RESOURCES MANAGEMENT COURSE

(A Pilot Study)

Statement of the Problem

Probably the most basic question about concept maps that needs to be answered is whether concept maps and the act of concept mapping acutally influence the learning of the intended concepts. Accordingly, this study attempted to determine the effects of concept mapping upon student achievement. The research hypothesis was that subjects who receive a concept map as a study aid will perform significantly better on an achievement test than subjects who do not receive a concept map.

To answer this question and gain further insight into the concept mapping technique, two additional issues were explored:

1. What are students' attitudes toward selected aspects of concept mapping, including perceived usefulness and the ease with which the technique is learned?
2. How does an oral instructional program in concept mapping compare with a program conducted solely with written materials in terms of effects upon attitudes and achievement?

Method and Procedures

Population and Sample

Students taking Natural Resources 201 (NR 201), Introduction to Natural Resources Management, at The Ohio State University during Spring Quarter, 1981 constituted the target population for this study. The majority of course participants were sophomores majoring or planning to major in one of the natural resources programs at Ohio State. Approximately 15% of the students were from departments other than Natural Resources.

Sixty volunteers from among the 185 students registered for the course were requested by the researcher, with the incentive that persons taking part in the project would be excused from some homework assignments. Fifty-three students agreed to participate, and 44 completed their assigned roles in the study. Although time did not permit the researcher to determine why nine of the volunteers failed to fulfill their parts in the project, it was learned that four had dropped the course during the time the study was being conducted.

Students were assigned to one of four treatment groups based upon their availability for scheduled instructional and testing sessions.

Treatments

The four groups received treatments and completed test instruments as follows.

Group 1: Posttest Only Control Group

This group was to have constituted a posttest only control group for the study. However, since less than the desired 60 students volunteered for the project, Group 1 was eliminated from the study group.

Group 2: Pretest-Posttest Control Group

Students assigned to this group completed a sentence generation pretest and an identical posttest on water resources concepts (see below and Pilot Study Appendix A) in 50-minute sessions scheduled before or after NR 201 class.

Group 3: Concept Mapping Group -- Written Program

This group of students received a packet of written materials designed to 1) demonstrate the value of concept maps in learning new information, and 2) show how to construct concept maps. As a homework assignment, each subject in this group constructed a map of selected concepts (see Figure 4). In addition, these students were given a concept map of water resources concepts at the beginning of the scheduled three-lecture presentation on water resources management in NR 201 (Figure 5). These students also completed the sentence generation pretest and posttest on water resources concepts.

Group 4: Concept Mapping Group -- Oral Program

Subjects in this group participated in a 50-minute instructional session on concept mapping conducted by the researcher. The information was essentially the same as that presented in written

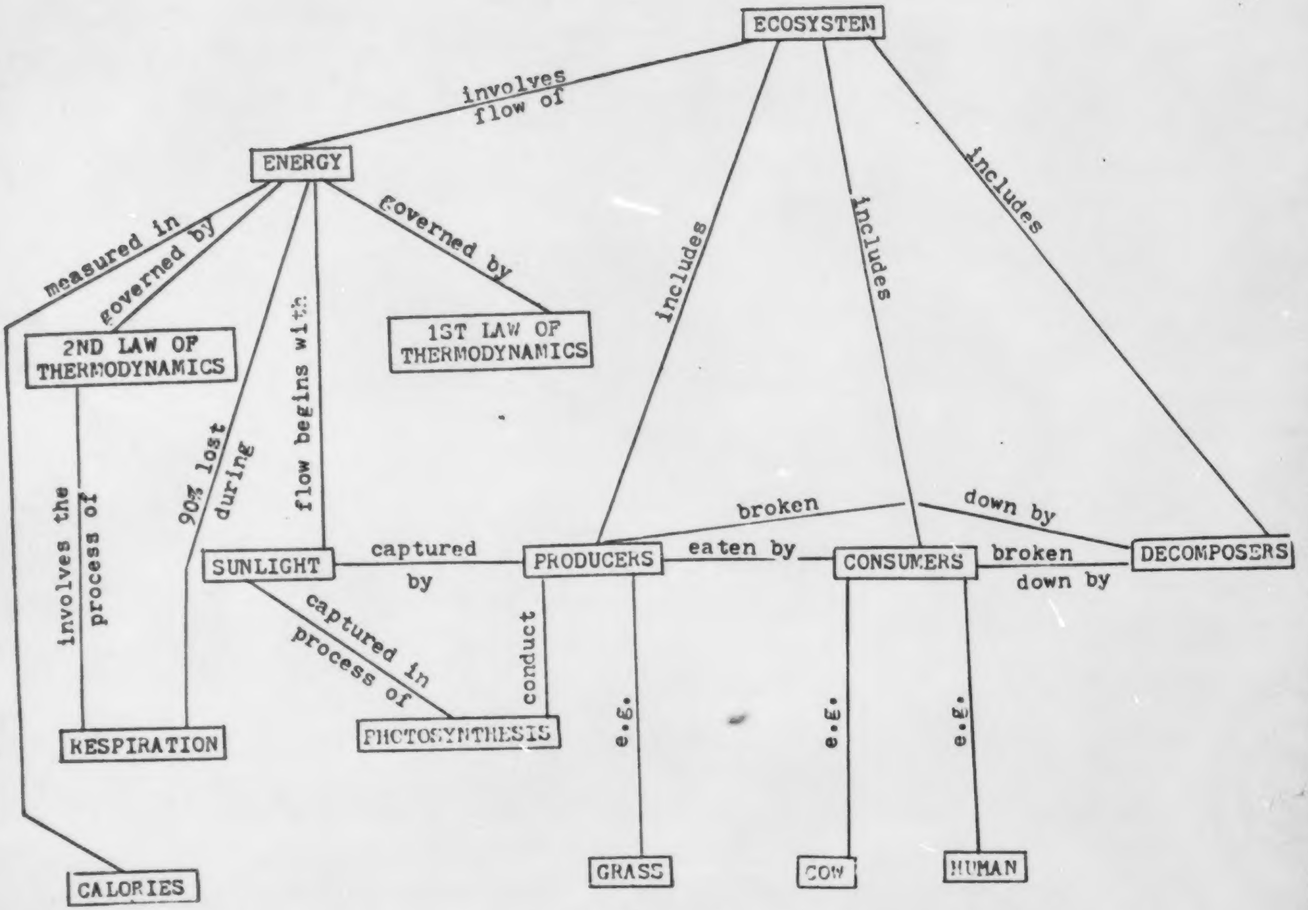
ECOSYSTEM
involves flow of
ENERGY
includes
includes
includes
measured in
governed by
flow begins with
governed by
2ND LAW OF THERMODYNAMICS
1ST LAW OF THERMODYNAMICS
involves the process of
90% lost during
broken down by
SUNLIGHT
captured by
PRODUCERS
eaten by
CONSUMERS
broken down by
DECOMPOSERS
captured in process of
conduct
e.g.
e.g.
e.g.
RESPIRATION
PHOTOSYNTHESIS
GRASS
COW
HUMAN
CALORIES

Figure 4
Ecosystem and Energy Flow Concept Map

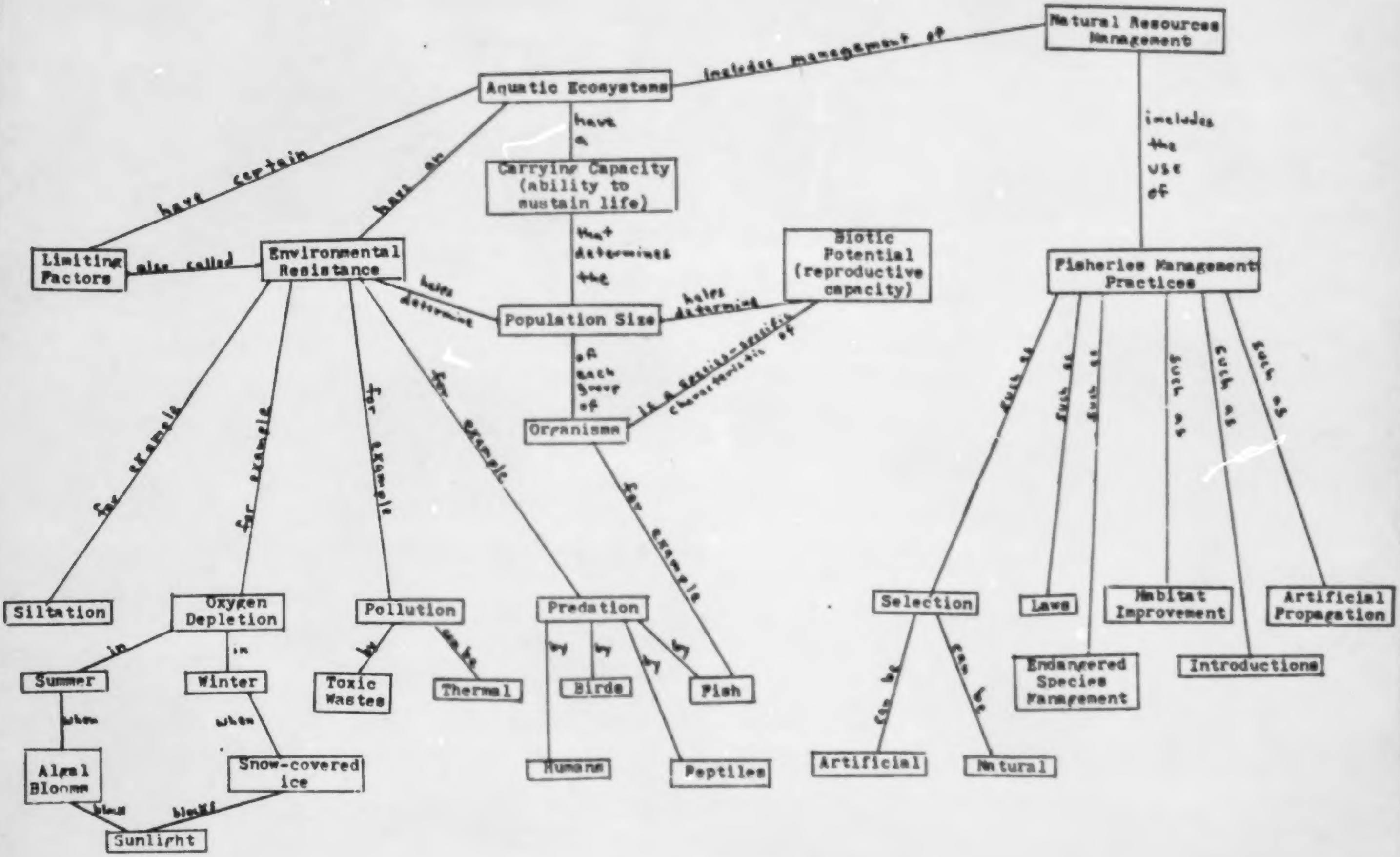
Natural Resources Management
includes management of
Aquatic Ecosystems
have certain
have an
have a
Carrying Capacity (ability to sustain life)
that determines the
Limiting Factors
also called
Environmental Resistance
helps determine
Population Size
helps determine
Biotic Potential (reproductive capacity)
of each group of
Organisms
is a species-specific characteristic of
includes the use of
Fisheries Management Practices
such as
for example
Siltation
Oxygen Depletion
in
Summer
when
Algal Blooms
blocks
in
Winter
when
Snow-covered ice
blocks
Sunlight
Pollution
by
Toxic Wastes
can be
Thermal
Predation
by
Humans
Birds
Reptiles
Fish
Selection
can be
Artificial
Natural
Laws
Endangered Species Management
Habitat Improvement
Introductions
Artificial Propagation

Figure 5
Map of Water Resources Concepts

form to Group 3, and it was given following a NR 201 class period. These students also completed the sentence generation posttest on water resources concepts. They were not pretested so that the effect of testing could be measured by comparing posttest scores of Groups 3 and 4. Like Group 3, this group received a water resources concept map before NR 201 lectures.

Instrumentation

Three assessment procedures were used in this study: 1) Pretest-Posttest on Water Resources Concepts, 2) Concept Map Scoring Procedure, and 3) Concept Map Attitude Assessment.

Pretest-Posttest on Water Resources Concepts[6].

This instrument assessed students' knowledge of some concepts and principles related to water resources management (see Pilot Study Appendix 1). Students were given a list of concept labels of interest to the researcher and asked to write one or more sentences that described how selected pairs of trios of these concepts related to each other. That is, students were asked to write out the principles that they possessed in cognitive structure which meaningfully linked concepts.

Concept Map Scoring Procedure:

Concept maps constructed by students in Group 3 and Group 4 were evaluated according to criteria developed by Novak (1981). Assessed through this procedure are a map's number of correct and explicit relationships, degree of hierarchy, degree of branching, whether or not it exhibits a general-to-specific organization, and number of cross links.

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[6] This procedure has been adapted from Van Kirk (1979) as described by Stewart (1980).

Novak's criteria were modified slightly in that the degree of hierarchy in the "master concept map" constructed by the researcher (see Figure 4) was considered the optimum hierarchy in this study. That is, students' maps received less than full credit on the hierarchy criterion if they exhibited either greater or lesser hierarchy than the master map. This change was made because several maps submitted by students were essentially linear word chains; they showed many hierarchical levels but few branches or cross links. Rather than giving these maps extra points for their greater hierarchy but corresponding lack of complexity, it appeared more appropriate to consider the degree of hierarchy shown in the master map as optimal.

Concept Map Attitude Assessment:

This instrument permitted the assessment of student attitudes regarding concept maps. It contained 12 Likert-type items and was administered to Groups 3 and 4 at the same time as the post-test on water resources concepts.

Table 32 summarizes the treatments and tests each group received.

Table 32

Summary of Treatments and Tests by Treatment Groups

Group	Pre-Test	Map Instruction	Map Provided[a]	Scored Map	Post-test	CMAA[b]	N of Subjects
1	no	none	no	no	yes	no	-
2	yes	none	no	no	yes	no	14
3	yes	written	yes	yes	yes	yes	13
4	no	oral	yes	yes	yes	yes	12

[a] Group received a map of water resources concepts prior to three 50-minute lectures on water resources given in NR 201.

[b] Concept Map Attitude Assessment

Results

Attitudes Towards Concept Mapping

During the time the water resources concepts posttest was administered, students in Groups 3 and 4 also completed the 12-item Concept Map Attitude Assessment (CMAA). Results are depicted in Table 33.

Table 33

Subjects' Attitudes Towards Concept Maps (N=25)

Attitude Item	SA	A	N	D	SD	Central Tendency[a]
1. Concept maps can help me learn concepts.	8	16	1	0	0	4.2
2. Learning how to make a concept map is difficult.	4	4	4	6	3	3.2
3. If someone gives me a concept map on a topic before I study the topic, I would understand that topic better.	10	31	1	1	0	4.3
4. Making concept maps is a waste of time.	1	1	3	16	4	2.0
5. I do not plan to make any more concept maps to help me study material presented in NR 201.	1	4	15	3	2	3.0
6. I think I would learn more by making my own concept map than I would by reading one made by an instructor.	4	6	7	6	2	3.2
7. Making concept maps is easy.	3	3	6	11	2	2.8
8. I plan to make concept maps to help me study material presented in courses other than 201.	1	8	10	5	1	3.1
9. By participating in this research project on concept maps, I have a better understanding of how people learn.	4	14	4	3	0	3.7

Table 33 (continued)

Attitude Item	SA	A	N	D	SD	Central Tendency
10. I understand what is meant by the term "meaningful learning."	1	19	3	2	0	3.9
11. I don't know the difference between the terms concept, object, and event.	0	0	0	15	10	1.6
12. Understanding the concept maps made by the researcher (on photosynthesis, ecology, and aqautic ecosystems) was difficult.	0	2	4	15	4	2.2

[a] Strongly Agree=5 ... Strongly Disagree = 1. The mean is reported except for questions 3, 4 and 10. Since skewness was greater than an absolute value of 1 in these cases, the median is given as a measure of central tendency.

Questions 1, 3, 4, 9, 10, 11, and 12 on the CMAA dealt with various aspects of students' perceptions of the usefulness of concept mapping. As the means and medians depicted in Table 2 indicate, responses to positively-worded items in this group center around 4.0 (Agree) while responses to negatively-worded questions approximated the corresponding score of 2.0 (Disagree). Thus, students tended to positively regard the potential usefulness of concept maps.

The remaining five CMAA items attempted to determine how easily participants felt concept mapping could be learned and whether they personally planned to construct additional concept maps after the conclusion of the research project. Responses to this group of items were generally "Neutral" (3.0).

Comparison of Concept Mapping Instructional Programs

Attitudes of students in Group 3 which received written instruction in concept mapping, and Group 4 which participated in an oral instructional session were measured by the CMAA. T-test contrasts on each of the instrument's 12 items revealed no significant differences at the .05 level in attitudes between groups on any item.

In addition to attitudinal responses, concept map scores of Groups 3 and 4 were also compared, both as total score and on each of Novak's five separate scoring criteria. Again, T-tests indicated that no significant differences existed between subjects in the oral session and subjects who used written materials ($p > .05$). Therefore in Table 34 on the next page which presents concept map scores, the scores of Group 3 and Group 4 are combined.

Differences in posttest scores of students in the written and oral concept map instructional programs were also analyzed. Since the water resources concepts posttest evaluates effects of concept maps upon achievement, comparisons of posttest results are discussed in the following section.

Table 34

Concept Map Scores
Broken Down by Scoring Criteria (N=22)

Scoring Criterion	Master Map Score	Average Subject's Map Score (#)	Average Subject's Map Score (%)
Relationships	19	8.2	43.0
Hierarchy	3	2.1	71.5
Branching	10	4.1	41.1
General-to-specific	5	3.8	76.4
Cross Links	6	1.9	31.7
Total	43	20.1	46.7

Effect of Concept Maps upon Student Achievement

A T-test revealed no significant difference ($p > .05$) in scores on the water resources concepts pretest between Group 2 and Group 3. Even though subjects were not randomly assigned to treatment groups, equivalence on the pretest allows a meaningful comparison of these two groups' posttest scores.

A one-way analysis of variance was performed on the mean posttest scores of Groups 2, 3 and 4. Table 35 lists means and standard deviations by group; Table 36 portrays results of the ANOVA.

The F ratio was significant at the .05 level, so follow-up comparisons using Tukey's least significant difference contrast were conducted. These analyses revealed that students in Group 4 significantly outperformed subjects in Group 3 and Group 2 on the water resources concepts posttest ($p < .05$). The small difference in mean scores between Groups 2 and 3 was not found to exceed the .05 significance level.

Table 35

Posttest Means
and Standard Deviations by Groups

Group	N	Mean	S.D.
2	14	23.2	7.16
3	13	23.8	6.94
4	12	29.6	6.08
Total	39	25.4	7.18

Table 36

ANOVA Summary Table of
Posttest Scores by Groups

Source	df	SS	F
Treatment	2	308.26	3.36*
Error	36	1650.96	
Total	38	1959.22	

*$p < .05$

Discussion and Implications

Subjects were not randomly drawn from the target population, so results of this study cannot by statistical logic be generalized from the volunteer participants to all students enrolled in NR 201 during Spring Quarter, 1981. Nevertheless, the findings reported above provide several insights into the concept mapping technique.

Opinions expressed by students on the Concept Map Attitude Assessment show that subjects did view concept maps as having potential to help them learn environmental concepts of the type presented in Natural Resources 201. However, responses were diverse, averaging out to "neutral," on CMAA items which dealt with how students felt about their competence in making concept maps and their plans to construct additional maps in the future.

A glance at Table 34, which shows scores on the concept maps that students produced, offers a plausible explanation for participants' ambivalent opinions about their own skills and use of concept maps. The average concept map recieved a score of 20.1 points, which is only 46% of the master map's score of 43 points. A breakdown of these scores by the five evaluation criteria indicates that subjects had particular difficulty in identifying content-correct conceptual relationships and delineating concept map branches and cross links. Several students discussed these aspects of concept mapping in response to an open-ended question on the attitude instrument. From this information and data, it appears that more time in a concept mapping instructional program needs to be devoted to assisting students in making their own concept maps and to providing feedback on completed maps. Special emphasis should be placed upon selecting the words which describe principles that meaningfully link one concept with another.

No significant differences in attitudes or concept map scores were found between the group that used written instructional materials and the group which was instructed orally. The optimum approach would probably be a combination: introductory written materials to define the term "concept" and describe meaningful learning, followed by an oral discussion of concepts and meaningful learning with oral group instruction in making concept maps. A written supplementary manual on concept mapping, with several step-by-step examples provided, should assist students in producing more complete and personally useful maps.

A design error severely limits conclusions which can be drawn about the effects of concept mapping upon student achievement as measured by the water resources concepts posttest. Students in Group 4 (Concept Mapping Group -- Oral Program) outperformed students in Group 2 (Pretest-Posttest Control Group) as well as students in Group 3 (Concept Mapping Group -- Written Program). Since no pretest data were collected on subjects in Group 4, their higher posttest scores could be due to either the treatment or initial differences from the other groups.

Groups 2 and 3, found to be statistically equivalent on the pretest, did not differ significantly on the posttest. The provision of a concept map on water resources concepts, therefore, did not result in significantly higher posttest scores in Group 3. Although it could be argued that the posttest does not measure concepts presented on the concept map, a subjective comparison of the map with the instrument shows close correspondence. A more tenable explanation for the results is that simply providing a concept map does not guarantee that students will actually use it. This may be especially true when concept maps are unfamiliar to students. One way that should encourage students to employ concept maps in reviewing course material would be to use them, as Bogden (1977) did, as the focus of group discussion sessions.

Thus, this exploratory study offers guidance for future instruction in and research on concept mapping. Students can be favorably disposed toward the potential for concept mapping to enhance their learning even though they may not be completely confident in their ability to construct maps. The effectiveness of concept maps in promoting concept learning remains to be assessed. Among the additional questions raised by this study are these: Is having students make their own maps more effective in facilitating concept attainment than providing instructor-constructed maps as study aids? What factors influence the degree to which learners benefit from concept maps? How can concept mapping best be integrated into educational practice? Once the potential, effectiveness and limitations of concept mapping are better known, the application of the technique to environmental education can be assessed and facilitated.

PILOT STUDY APPENDIX 1:

PRETEST AND POSTTEST ON WATER RESOURCES CONCEPTS

Listed on the next page are a dozen concepts that relate to natural resources management. You will probably recognize some of these concepts but may be unfamiliar with others. I am interested in knowing how you feel these concepts are related to each other.

On the following pages, you will be asked to use two or more of these concepts at a time in sentences. Try to express what you feel to be important about how they relate to each other. Below is a brief example from ecology:

Concept List

Community
Ecosystem
Niche
Organism
Population
Succession

Task 1

Write up to three sentences to show how the concepts population and community are related. Do not use any of the other concepts in the list.

(Sample Answer)

1. If the populations in an area change, the community will also be different.
2. All populations in a given area compose a community.
3. Different communities have different populations.

Task 2

Now try to express the relationship between population and community also using one or more of the other concepts from the list. Write up to three sentences.

(Sample Answer)

1. The change in populations and thus communities in one area is called ecological succession.

Your test consists of 10 tasks and begins on the next page.

Concept List

- Algae
- Biotic Potential
- Carrying Capacity
- Decay
- Environmental Resistance
- Habitat Improvement
- Oxygen Depletion
- Photosynthesis
- Population Size
- Summer
- Sunlight
- Winter

Task 1

Write up to three sentences to show how the concepts algae and sunlight are realted. Do not use any of the other concepts in the list.

Task 2

Now try to express the relationship between algae and sunlight also using one or more of the other concepts from the list. Write up to three sentences.

Task 3

Write up to three sentences to show how the concepts carrying capacity and population size are related. Do not use any of the other concepts in the list.

(continued next page)

Task 4

Now try to express the relationship between carrying capacity and population size also using one or more of the other concepts from the list. Write up to three sentences.

Task 5

Write up to three sentences to show how the concepts oxygen depletion and environmental resistance are related. Do not use any of the other concepts in the list.

Task 6

Now try to express the relationship between oxygen depletion and environmental resistance also using one or more of the other concepts from the list. Write up to three sentences.

Task 7

Write up to three sentences to show how the concepts oxygen depletion and algae are related. Do not use any of the other concepts in the list.

(continued next page)

Task 8

Now try to express the relationship between oxygen depletion and algae also using one or more of the other concepts from the list. Write up to three sentences.

Task 9

Write up to three sentences to show how the concepts carrying capacity and habitat improvement are related. Do not use any of the other concepts in the list.

Task 10

Now try to express the relationship between carrying capacity and habitat improvement also using one or more of the other concepts from the list. Write up to three sentences.

END OF TEST

Thanks for your cooperation. Do you have any comments about the test questions or test format? Please write them below:

APPENDIX B

COURSE SYLLABUS FOR
NATURAL RESOURCES 201, AUTUMN QUARTER, 1981

INTRODUCTION TO NATURAL RESOURCE MANAGEMENT
NATURAL RESOURCES 201

Autumn Quarter 1981
TRF 1:00 P.M.
131 Hitchcock Hall
Call #5698-7

Instructor:	Dr. C. L. Shepard Division of Environmental Education Rm. 224 Lord Hall 422-5589
Teaching Assistant:	Ms. Deb Bainer Division of Environmental Education Rm. 224 Lord Hall 422-5589

SYLLABUS

DATE	TOPIC	READING
9/24 R	Introduction and Course Overview Ms. Bainer/Dr. Shepard	
9/25 F	Ecological Basis for Resource Management C. L. Shepard	
9/29 T	Ecological Basis for Resource Management C. L. Shepard	Pgs. 21-47
10/1 R	Biogeography Ms. Bainer	Pgs. 47-53
10/2 F	History and Issues of Resource Management C. L. Shepard	Chapter 1
10/6 T	Current Institutions and Issues Ms. Bainer	
10/8 R	Water Resource Management Dr. J. F. Disinger, Div. of Environmental Education	Chapter 5
10/9 F	Marine Resources Dr. Rosanne Fortner, Div. of Environmental Education	Chapter 11
10/13 T	Water Management Dr. Rosanne Fortner, Div. of Environmental Education	Chapter 10
10/15 R	MIDTERM I	
10/16 F	Abiotic Resources Dr. Terry Logan, Department of Agronomy	Chapters 3 & 4
10/20 T	Energy: A Matter of Alternatives Ms. Bainer	Pgs. 718-746

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DATE	TOPIC	READING
10/22 R	Energy - Nuclear Dr. P. Schlosser, Dept. of Mechanical Engineering	Chapter 18
10/23 F	Energy - Fossil Fuels Mr. Woody Bousquet, Doctoral Candidate	Pgs. 691-718
10/27 T	Forest Industry Dr. R. Touse, Division of Forestry	Pgs. 256-266
10/29 R	Forest Resource Management Professor W. Cowen, Division of Forestry	Pgs. 266-313
10/30 F	Wildlife Management Dr. T. Townsend, Div. of Fisheries & Wildlife Mgt.	Chapter 9
11/3 T	MIDTERM EXAM II	
11/5 R	Conflicts in Resource Management C. L. Shepard	
11/6 F	Economic Costs & Benefits of Resource Management Dr. R. Vertrees, Resource Development Program	Chapter 20
11/10 T	Environmental Decay: Food/Population Ms. Bainer	Chapter 19
11/12 R	Politics of Natural Resources Dr. E. F. Murphy, College of Law	
11/13 F	Environmental Decay: Solid & Hazardous Waste Mr. W. Bunner, Safety Specialist	Chapters 15 & 16
11/17 T	Environmental Decay: Open Space/Land Use C. L. Shepard	Chapter 7
11/19 R	Resource Management for Leisure Time Dr. R. Douglass, Div. of Parks & Recreation Admin.	
11/20 F	Simulation in Resource Management Student Directed	
11/24 T	Environmental Decay: Air Quality Symposium	Chapter 13
11/26 R	HOLIDAY - NO CLASS	
11/27 F	HOLIDAY - NO CLASS	

DATE	TOPIC	READING
12/1 T	Communications for Resource Management Dr. Rosanne Fortner, Div. of Environmental Education	
12/3 R	Resource Management for the Future Dr. R. E. Roth, Div. of Environmental Education	Chapter 21
12/4 F	Resource Management - Where from Here? C. L. Shepard	

FINAL EXAM - - - MONDAY, DECEMBER 7th - - - 10:00 A.M.

NATURAL RESOURCES 201 AUTUMN QUARTER 1981

1. Course Description

Natural Resources 201 is an introductory course concerned with resource management problems and their possible solutions. It is designed to provide a foundation and general knowledge in the history, philosophy, technology and organization of natural resources and their management. Students who continue in the field of Natural Resources will find these areas treated in greater depth in more advanced courses. For students not in the School of Natural Resources, this may be your only exposure to the components which effect your everyday activities. This course presents a broad range of topics concerning natural resource management but strives to emphasize the interrelatedness of the environment and man.

2. Course Objectives

Upon completion of this course the student should be:

1. knowledgeable about the interrelated biophysical and socio-cultural environments;
2. aware of environmental problems and management alternatives useful in solving those problems; and,
3. motivated toward working to solve these problems both professionally and personally.

3. Text

Owen, Oliver S.; Natural Resource Conservation, 3rd Edition, 1980. MacMillan Publishing Co., New York.

N.R. 201 Course Packet (required) - Outlines and Supplementary materials. Available only at Derby Hall Bookstore

Readings and assignments will be made from both of the above to complement and supplement the lectures.

4. Exams

There will be two midterm exams and a final exam. Questions for these exams will be taken from the lectures and reading assignments. If you are unable to take an exam on the scheduled date, you are responsible to pre-arrange for a make-up exam. Make-ups must be completed within one week of the exam date.

5. Participation and Attendance

Part of your final grade will be based upon participation and attendance. These components of your grade will be evaluated through in-class writing exercises and short out-of-class assignments. No assignments will be accepted late.

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6. Grading

Your grade will be determined as follows:

Midterm Exam I	100 points
Midterm Exam II	100 points
Final Exam	200 points
Participation & Attendance	100 points
	500 points total

(Total x 2 = 1,000 total points possible)

Your letter grade will be assigned as follows:

1,000-930	A
929-900	A-
899-875	B+
874-825	B
824-800	B-
799-775	C+
774-725	C
724-700	C-
699-650	D+
649-600	D
599 and below	E

7. Office Hours

Dr. Clint Shepard, 224 Lord Hall 422-5589	TR 2:00-4:00 P.M. W 9:00-11:00 A.M. or by appointment
Ms. Deb Bainer, 224 Lord Hall 422-5589	MF 9:00-11:00 A.M. or by appointment

APPENDIX C

SCRIPTS AND WORKBOOKS FOR CONCEPT MAPPING INSTRUCTIONAL MODULES

CONCEPT MAPPING: A STRATEGY FOR LEARNING CONCEPTS

SCRIPT -- GROUP 1: HP

Slides	Narration
CONCEPT MAPPING: (1)	Concept mapping ...
A STRATEGY FOR LEARNING CONCEPTS (2)	... is a strategy designed to help people learn concepts. This slide-tape program and the accompanying Concept Mapping Workbook and Instruction Manual ...
(cover of workbook) (3)	...will assist you in understanding, constructing and using concept maps. If you have not already done so ...
GROUP 1 (4)	... write your name, your group number and the time it is now in the spaces provided on the Assignment Sheet, which is the last page in your manual. ...Make sure ...that the number on this slide matches the number of the concept mapping group you were assigned to. If the numbers do not match, stop here. You cannot receive credit for completing this module unless you use the right program. Obtain the correct slide-tape program, if necessary, before continuing further. ...
(person writing on worksheet) (5)	You will fill out several workbook exercises while listening to this program. These exercises begin on page 3 of your manual. ...Feel free to turn the program off if you need more time to complete a workbook exercise.
OBJECTIVES (6)	After completing this module, you should be able to define a concept ...
CONCEPTS (7)	...and distinguish concepts from objects and events.
MEANINGFUL LEARNING (8)	You should be able to explain how concepts help people learn... and describe what is meant by the term "meaningful learning." You should also be able to explain ...
(person making a concept map) (9)	...how making a concept map ... can help people learn concepts meaningfully.
(person using Manual and text to make concept map) (10)	And finally, you should be able to make your own concept maps ... according to the directions explained in this program... and summarized in your Instruction Manual

... = pause

PART ONE (11)	Turn to page 3 of your Concept Mapping Workbook and Instruction Manual. (5 second pause)
(match, pencil, wooden nickel, index card, screwdriver w/ wooden handle) (12)	(2 second pause) Consider these objects. ... What do they have in common? (4 second pause) Write your answer on the worksheet below the line labeled "Exercise 1." (10 second pause)
(penny, wooden nickel, dime, quarter, dollar bill) (13)	Here is another group of objects. Whey do they have in common? ... Write your answer below the line marked "Exercise 2." (10 second pause)
(hammer w/ nail, scissors cutting card, ice in jar lid) (14)	Here are some events. ... What do they have in common? ... Write your answer on the worksheet. This is Exercise 3. (10 second pause)
(composite of objects in slides 12, 13, and 14) (15)	For each of these questions, you were asked to identify what the objects or events had in common. ...
REGULARITY (16)	That is, you had to determine what the regularity in each group was. ...
(slide 12) (17)	You may have written "household objects" or "wood" for the first group. ...
(slide 13) (18)	For the next group, "money" is a possible answer. You could also have used the word "solids" to describe these objects. ...
(slide 14) (19)	There are many words that could describe the regularity in these events. ... Among the possibilities are "change," "action," "phenomenon," and "physical change."
(brick building) (20)	Trying to find out what the objects and events we encounter have in common is something we do every day. Remembering every object we see would require an overwhelming amount of mental activity...
(close-up brick wall of building) (21)	so we usually look for regularities in these objects ... and use labels to describe these regularities and communicate them to other people.

(leafy tree) (22)	For example, instead of cataloguing all the specific details of each and every leaf we see on a tree, ... we mentally apply the label "leaf" to these perceptions.
(close-up of a few leaves) (23)	These objects, although each is unique, have enough features in common to enable us to use the label "leaf" to name them all. ...Of course, there are times when we may want to distinguish between maple leaves and dandelion leaves, so more specific labels are often needed.
CONCEPTS (slide 7) (24)	The regularities that we perceive in objects and events are called concepts. ...We usually invent a label for each concept so we can communicate that concept to someone else.
OBJECTS EVENTS CONCEPTS (25)	It is important to distinguish among the three words we have been discussing: objects, events and concepts. ...An object is something that exists. An event is something that happens. And a concept...is a regularity in objects or events that we designate with a label. ...
(my watch) (26)	A concept is general objects and events are specific. ... "watch" is a concept. ... "My watch" is a specific object. ..."Baseball game" is a concept. ...The Reds' game on April 11th was a specific event. ...See if you can distinguish among concepts, objects and events. Turn this tape recorder and slide projector program off, and complete Exercise 4 in your workbook. (10 second pause)
EXERCISE FOUR (27)	Could you distinguish among the objects, events, and concepts listed? Examples a, b, c, and e refer to things that are specific and concrete: my car, your breathing, etc. Thus, a, b, c and e are not concepts. Since a and b refer to things that exist, they are objects. Examples c and e are events because they stand for things that happen. Notice that examples d, f, g, and h do not refer to specific deer, clocks, etc. Instead, they represent all clocks, any deer, any biome, and all instances of patriotism. These, then, are regularities. They are examples of concepts. ... What other concepts have you learned recently?...
PART TWO (28)	Why all the emphasis on concepts? Because concepts are the mental building blocks that humans thing with. ...
(busy street scene) (29)	As we have discussed, individual events and objects in our surroundings are just too numerous for us to deal with in any meaningful way. ... So, we attempt to identify regularities...

(close-up of two street signs from slide 24) (30)	...in the groups of objects and events we encounter. ... These regularities -- which you now know are called concepts -- make thinking, learning, and communicating possible by "packaging" the information into a form we can use.
(person examining berries on bush) (31)	How do people learn concepts? Most educators agree that we learn concepts that are unfamiliar to us ... by relating new concepts to concepts we already know. ...
MEANINGFUL LEARNING (slide 8) (32)	That statement probably comes as no surprise to you. All that educators are saying is that to learn new concepts you must find some meaning that helps you logically link the unfamiliar concept ... to a concept you already understand. This process is often called meaningful learning. ...
(person reading text) (33)	The idea of meaningful learning is probably not new to you. It certainly makes sense! Unfortunately, many of us memorize concepts. Memorization is not meaningful learning, because in memorization you are just repeating the concept label over and over again in the hope that you'll remember it for the exam. Meaningful learning requires a different strategy. ... To learn a concept meaningfully, you must first
(text opened to page on energy) (34)	identify the concept to be learned. ... Next, you need to think of a concept you already know...
(light switch, thermometer, and "save energy" sticker) (35)	... that has a logical, meaningful relationship to the new concept.
(person eating an apple) (36)	And third, try to relate the newly-learned concept to other concepts you already know. ...If you take the time to learn all concepts meaningfully, you will remember them longer... and be able to make better use of your existing knowledge to learn new concepts.
PART THREE (37)	Before you begin Part Three, stand up, stretch, and think about what has been presented so far. Turn the tape recorder and slide projector off, and take a break. (10 second pause)
(items made of pure metal) (38)	Read Exercise 5 in the workbook. (10 second pause
(items made of alloyed metals) (39)	(10 second pause) Cover the paragraph with a book when you're finished reading. (5 second pause) Without looking at the paragraph, listen to the following questions. Write your answers on the worksheet under Exercise 6.

EXERCISE SIX (40)	Question 1: What is the best one-word lable for the subject of the paragraph you just read?...The question again, What is the best one-word label for the subject of the paragraph you just read?... Question 2: What is one difference between pure metals and alloys?...Again, what is one difference between pure metals and alloys?... Question 3: What are alloys made of?...The question again, What are alloys made of?... Question 4: List two common, natural metals that were mentioned in the paragraph. ...Question 4 again, List two common, natural metals that were mentioned in the paragraph. ... Question 5: Five metals are listed on the worksheet. Circle the two that are alloys. ... Again, Five metals are listed on the worksheet. Circle the two that are alloys. ...
CONCEPT MAP (41)	Now, examine the concept map on the next page of your workbook. (25 second pause)
(metals concept map; same as workbook) (42)	What does the concept map do with the information that was presented previously in paragraph form?...How do you think the concept map might help you learn?...
CONCEPT MAPS... 1. IDENTIFY 2. ORGANIZE (43)	Concept maps have several features. First, they identify the concepts to be learned. ...Second, they organize these concepts into a hierarchy; that is, the most general and inclusive concept (natural resources) is at the top, while the least inclusive examples (gold, copper, and steel, for example) are at the bottom. ...
CONCEPT MAPS... 3. LINK 4. LABEL (44)	Third, the concepts that are related to each other are linked by lines. ... And finally, these linking lines are labelled with words that meaningfully relate the concepts to each other. ...
(concept map with concepts underlined in green) (45)	A concept map can be an effective learning strategy because it features concepts -- the mental "building blocks" that people think with. ...
(concept map with links underlined in green) (46)	In addition, a concept map shows how concepts are linked together. These linking lines have labels so that you can meaningfully -- not arbitrarily -- relate concepts to each other as you learn them. ...

("General" and "Specific" labels on concept map) (47)	And finally, the hierarchical arrangement helps you distinguish the general concepts, which are the most important, from the more specific examples. All too often, we focus attention on the example instead of learning the major concepts. ... Exercise 7 in your workbook involves you in making a concept map. Turn the tape recorder and slide projector off while you are completing the exercise. Once you are finished, turn the equipment back on. (10 second pause)
(slips of paper with concepts written on them) (48)	Let's take the concept mapping procedure step by step. The first step is to identify the concepts -- the regularities in objects or events -- described in the paragraph. These include photosynthesis, process, plants, solar energy, carbon dioxide, water, sugar molecules, chlorophyll, green pigment, and catalyst. It's surprising to see how many concepts can appear in a single paragraph! By writing each of these concepts on a small slip of paper, they can be easily organized.
(concept labels arranged) (49)	Next, the concept labels should be arranged from the most general, or most inclusive...to the most specific. The most general concepts go to the top, the most specific concepts go to the bottom, and the concepts of immediate importance go somewhere in between. In our example, the entire paragraph deals with a process that plants conduct called photosynthesis, so these concepts may be considered the most general and belong at the top of the map. "Green pigment" and "550 billion tons daily" are specific concepts. Therefore, they belong at the bottom of the map. ...
(concept labels grouped) (50)	At this point, you should group the concepts that are related to each other. For example, both "catalyst" and "green pigment" describe the concept "chlorophyll," so the three concepts belong together. ...
(concepts linked) (51)	The next step is to identify the principles -- these are linking words that verbally tie concepts to one another. ... For example, photosynthesis is a process that utilizes solar energy. ...
(completed concept map on photosynthesis) (52)	Finally, you have to organize the concepts and principles into a completed map. ...This can be quite a juggling act. ... You will probably have to try several patterns of concepts and concept links before you find an organizational set up that means the most to you. ... In your Instruction Manual on page 8...is one of many possible maps that can be constructed from the photosynthesis paragraph. ... Since everyone assigns slightly different meanings to concepts, there is no one "correct" concept map. The best map is the one that is most meaningful to you.
CONCEPT MAP EVALUATION (53)	Some concept maps, however, are more complete than others. How can a concept map be evaluated? ...

HIERARCHY: General to Specific (54)	First, the concepts should be arranged in a hierarchy.
(slide 47) (55)	That is, a good concept map starts with the most general concepts at the top and proceeds down to the most specific concepts.
RELATIONSHIPS: *Accurate *Labeled *Adequate No. (56)	Next, the relationships should be accurate and labeled properly. The number of relationships should be adequate. That is, all of the important relationships should be shown on the map. ...
(slide 52, with relationships highlighted) (57)	The relationships on the photosynthesis concept map are marked in yellow. ... While the relationships and general-to-specific hierarchy of a concept map are the most important features, concepts maps may be judged in other ways. ...
(slide 52, with branches highlighted) (58)	Notice that the concepts "process", "chlorophyll", and "carbon dioxide" connect to several concepts that are placed lower on the map. ... The more upper-to-lower connections you can identify, the better the concept map ... because it will be more meaningful. ...
(slide 52, with cross link highlighted) (59)	The photosynthesis concept map also shows a cross link ...between concepts located at the same level of the map. These cross links also make the concept map more meaningful. ...
SUMMARY (60)	This slide-tape program was intended to accomplish several objectives. ...
CONCEPTS (slide 7) (61)	What is a concept?...You should recall that a concept is a regularity in objects or events...that we identify with a label. People use concepts to organize their perceptions of the world around them. ...
MEANINGFUL LEARNING (slide 8) (62)	This program also described how people learn concepts. ... Humans learn unfamiliar concepts by linking them to concepts they already know. ...This process is called meaningful learning.
(slide 52) (63)	And finally, the concept mapping strategy was explained. You should understand...what a concept map is...how it can help you learn...and how to make one...Instructions and sample concept maps are included in your Concept Mapping Workbook and Instruction Manual. ...
(text, scissors, slips of paper, and manual) (64)	Refer to your manual when constructing the three maps that will be assigned in Natural Resources 201. ... Of course, you are encouraged to make additional maps and use them as study aids.

(Assignment sheet and pencil) (65)	Turn to the Assignment Sheet, which is the last page of the manual. ... Record the time it is now in the space provided. ... After turning in the slide-tape program, answer the questions, tear off the Assignment Sheet, and turn it in on the date indicated.
THE END (metal turtle and letters) (66)	This concludes the concept mapping module. Concept maps have a great potential to help people learn concepts meaningfully, and I hope you will find the strategy to be a useful one in your studies. ..

Name: ______________________

CONCEPT MAPPING WORKBOOK AND INSTRUCTION MANUAL

Concept mapping is a strategy designed to help people learn concepts. These materials and the accompanying slide-tape module will assist you in understanding, constructing and using concept maps.

Included in this workbook and manual are:

1. Directions for completing the concept mapping learning unit as required for this course.
2. Several workbook exercises which you will fill out while listening to the slide-tape program.
3. A manual which will serve as a reference guide to help you construct concept maps.
4. An assignment sheet to complete and hand in to the course instructor.

The slide-tape program will be available from Monday, October 12 through Thursday, October 22 in two campus locations. Information about how to obtain this program appears on the next page. The program must be completed and the assignment sheet turned in by Thursday, October 29.

Read the directions section before you begin the slide-tape module.

Group 1

Directions

You have been randomly assigned to one of three concept mapping groups. The group number appears on the preceeding page.

All groups will complete the same assignments. The only difference will be that each group will learn and use a different version of the concept mapping strategy.

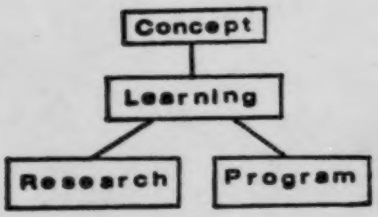
In order to help us determine which version should be used in future Natural Resources 201 classes, it is extremely important that you do not discuss concept mapping with other students. This will insure that students in each group will use only their assigned concept mapping strategy. Your cooperation will enable us to make the right decision.

The slide-tape learning unit is available from Monday, October 12 through Thursday, October 22 in the locations listed below.

Environmental Education (E^2) Research Lab (422-5589)
231 Lord Hall
Hours: M T R F 8:00am to 4:30pm
Wednesday 8:00am to 2:00pm
Closed evenings and weekdays
*Obtain materials in 246 Lord Hall.

West Campus Learning Resources Center (422-0183)
Lower level, Pressey Hall, West Campus
Hours: M T W R 8:00am to 10:00pm
Friday 8:00am to 5:00pm
Saturday 10:00am to 5:00pm
Sunday 2:00pm to 10:00pm
*Obtain materials at the A-V Circulation Desk.

Bring this manual, a notebook and your OSU student ID with you. Although the slide-tape unit itself should last approximately one hour, allow an hour and a half total so that you have enough time to check out materials and set up the equipment.



Workbook

*** Make sure that the number on the slide-tape module ***
matches your group number.

INTRODUCTION

Obtain the slide tray and tape. After you have set up the equipment, write your name, group number and the time in the spaces provided on the Assignment Sheet (last page).

PART ONE: CONCEPTS, OBJECTS, AND EVENTS

Exercise 1

What do the objects have in common?

Exercise 2

What do the objects have in common?

Exercise 3

What do the events have in common?

Exercise 4

Below is a list of objects, events and concepts. Place an "O" beside objects, an "E" beside the events, and a "C" beside the concepts.

___ a. my car

___ b. Bob Hope's nose

___ c. your breathing at this moment

___ d. patriotism

___ e. World War II

___ f. deer

___ g. clock

___ h. biome

Turn the program back on when you complete this exercise.

PART TWO: MEANINGFUL LEARNING

(There are no exercises in this part of the program.)

4

PART THREE: CONCEPT MAPPING

Exercise 5

Read the paragraph below.

Metals are natural resources with which everyone is familiar. Metals occurring free from other materials are pure metals. Some pure metals such as gold, silver and platinum are called precious metals because they are rare. Copper, tin, iron, and zinc are considered common because they are more abundant. People have learned to combine pure metals with other substances to create new metals, called alloys. Steel, brass and bronze are alloys.

Exercise 6

Question 1:

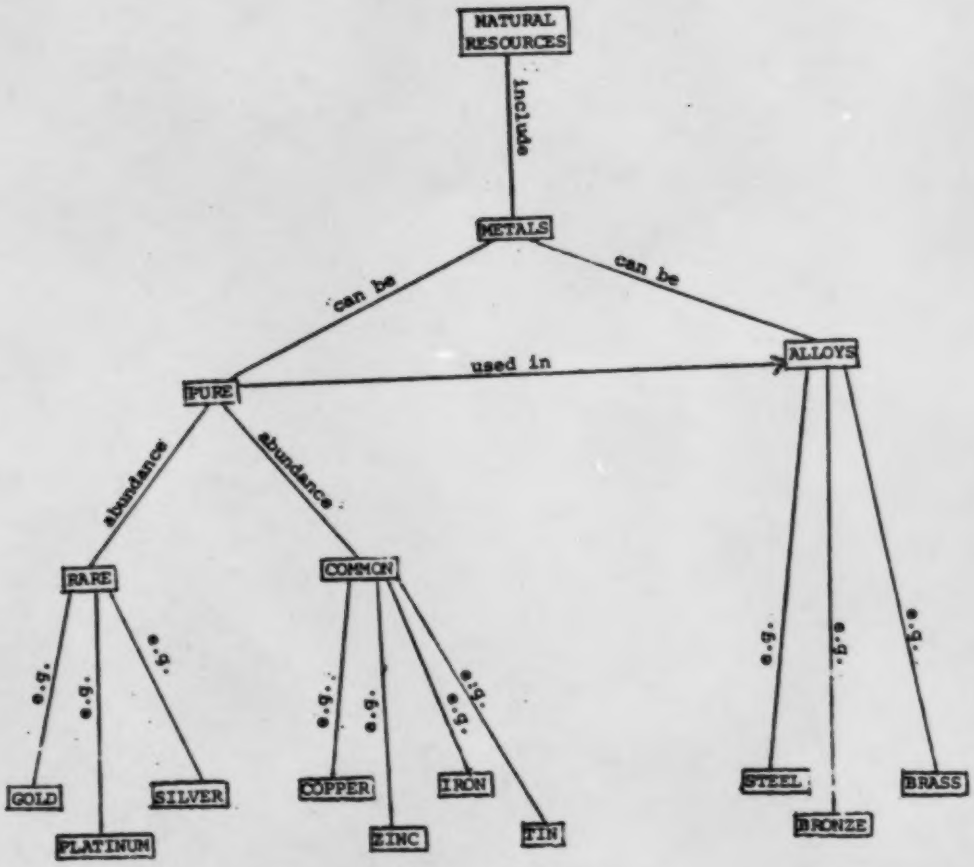
Question 2:

Question 3:

Question 4:

Question 5: platinum brass steel zinc tin

5


NATURAL RESOURCES
include
METALS
can be
can be
PURE
used in
ALLOYS
abundance
abundance
RARE
COMMON
e.g.
e.g.
e.g.
GOLD
PLATINUM
SILVER
e.g.
e.g.
e.g.
e.g.
COPPER
ZINC
IRON
TIN
e.g.
e.g.
e.g.
STEEL
BRONZE
BRASS

EXAMPLE OF A CONCEPT MAP

Exercise 7

Make yourself about two dozen slips of paper ½" by 2½", if those provided with the learning materials have already been used up. Read the directions in the Instruction Manual, page 7, for making a concept map.

Using these directions and the slips of paper, make a concept map from information presented in the paragraph below.

> Photosynthesis is a process by which plants utilize solar energy to convert carbon dioxide and water into sugar. The process can only occur if chlorophyll is present. Chlorophyll, a green plant pigment, serves as a catalyst for the photosynthesis reaction. In a sense, solar energy is "trapped" by chlorophyll and channeled into sugar molecules. The world's green plants fix 550 billion tons of carbon dioxide daily.
>
> — Adapted from Natural Resources Conservation (Owen, 1980, pp. 21-22).

When your concept map is completed, copy it onto a separate piece of paper. Turn the tape recorder and slide projector back on.

Instruction Manual

DIRECTIONS FOR CONSTRUCTING A CONCEPT MAP

1. Review the material presented or assigned.

2. Identify the concepts that appear most important. Write each of these on a small slip of paper.

3. Arrange the concept labels on a piece of paper from the most general (most inclusive) to the most specific (least inclusive). Put the most general concepts at the top of your paper, the most specific concepts at the bottom, and the concepts of intermediate importance somewhere in between.

4. Group concepts that are related to each other.

5. Identify a principle (word or phrase) that logically links each pair of concepts that are related to each other.

6. An example of a concept map is provided on the next page. Using this as a guide, show the relationships among the concepts in the material assigned. You will probably have to try several patterns of concepts and concept links before you find the organizational setup that makes the most sense to you.

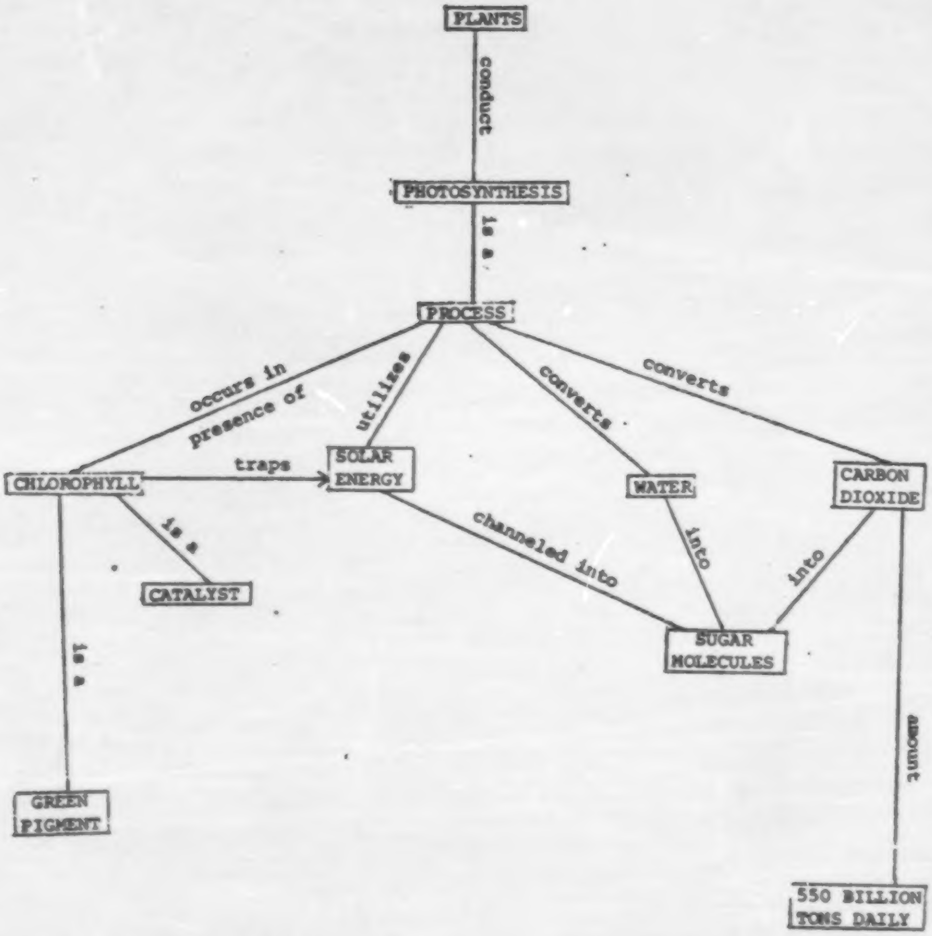
7. Check your final arrangement against these criteria. A concept map should have the following features:

    a. Concepts are arranged in a hierarchy. That is, the map starts with the most general concepts at the top and proceeds down to the most specific concepts.

    b. Related concepts should be linked by lines (principles) that show these relationships. All important relationships should be shown.

    c. Each principle has a label that describes the relationship you use to link the concepts to each other. Labels should be accurate and specific.

8. Copy the completed concept map onto a separate piece of paper.


PLANTS
conduct
PHOTOSYNTHESIS
is a
PROCESS
occurs in presence of
utilizes
converts
converts
CHLOROPHYLL
traps
SOLAR ENERGY
WATER
CARBON DIOXIDE
is a
CATALYST
channeled into
into
into
SUGAR MOLECULES
is a
GREEN PIGMENT
amount
550 BILLION TONS DAILY

CONCEPT MAP FOR PHOTOSYNTHESIS PARAGRAPH

Name: ______________________________

Assignment Sheet

Group #: ___________

Time you began the slide-tape program: __________________

Time you finished the slide-tape program: ________________

Date you used the slide-tape program: ___________________

Use your Instruction Manual and the information you learned during the slide-tape program to answer the following questions.

1. What is a concept?

2. How do concepts help people learn?

3. What features should a concept map have?

*** Due in class on Thursday, October 22 ***

CONCEPT MAPPING: A STRATEGY FOR LEARNING CONCEPTS

SCRIPT -- GROUP 2: H

Follow the HP script (Group 1) for slides 1 through 41.

Slides	Narration
(metals concept map; same as workbook) (42)	What does the concept map do with the information that was presented previously in paragraph form? ... How do you think a concept map might help you learn?...
CONCEPT MAPS... 1. IDENTIFY 2. ORGANIZE (43)	Concept maps have several features. First, they identify the concepts to be learned. ...Second, they organize these concepts into a hierarchy; that is, the most general and inclusive concept (natural resources) is at the top, while the least inclusive examples (gold, copper, and steel, for instance) are at the bottom. ...
CONCEPT MAPS... 3. LINK (44)	Third, the concepts that are related to each other are linked by lines. ...
(concept map with concepts underlined in green) (45)	A concept map can be an effective learning strategy because it features concepts -- the mental "building blocks" that people think with. ...
(concept map with links underlined in green) (46)	In addition, a concept map shows how concepts are linked together.
("General" and "Specific" labels on concept map) (47)	And finally, the hierarchical arrangement helps you distinguish the general concepts, which are the most important to learn, from the more specific examples. All too often, we focus attention on the example instead of learning the major concept. ... Exercise 7 in your workbook involves you in making a concept map. Turn the tape recorder and slide projector off while completing the exercise. Once you are finished, turn the equipment back on. (10 second pause).
(slips of paper with concepts written on them) (48)	Let's take the procedure step by step. The first step is to identify the concepts -- the regularities in objects or events -- described in the paragraph. These include photosynthesis, process, plants, solar energy, carbon dioxide, water, sugar molecules, chlorophyll, green pigment, and catalyst. It's surprising to see how many concepts can appear in a single paragraph! By writing each of these concepts on a small slip of paper, they can be easily organized.

... = pause

(concept labels arranged) (49)	Next, the concept labels should be arranged from the most general, or most inclusive...to the most specific. The most general concepts go to the top, the most specific concepts go to the bottom, and the concepts of immediate importance go somewhere in between. In our example, the entire paragraph deals with a process that plants conduct called photosynthesis, so these three concepts may be considered the most general and belong at the top of the map. "Green pigment" and "550 billion tons daily" are specific concepts. Therefore, they belong at the bottom of the map.
(concept labels grouped) (50)	At this point, you should group the concepts that are related to each other. For instance, both "catalyst" and "green pigment" describe the concept "chlorophyll", so the three concepts belong together. ...
(completed concept map on photosynthesis (51)	Finally, you have to organize the concepts into a completed map. ... This can be quite a juggling act. ...You will probably have to try several patterns of concepts before you find an organizational setup that means the most to you. ...In your Instruction Manual on page 8...is one of many possible maps that can be constructed from the photosynthesis paragraph. ...Since everyone assigns slightly different meanings to concepts, there is no one "correct" concept map. The best map is the one that is most meaningful to you.
CONCEPT MAP EVALUATION (52)	Some concept maps, however, are more complete than others. How can a concept map be evaluated?...
HIERARCHY: General to specific (53)	First, the concepts should be arranged in a hierarchy.
(slide 47) (54)	That is, a good concept map starts with the most general concepts at the top and proceeds down to the most specific concepts.
RELATIONSHIPS: *Accurate *Adequate No. (55)	Next, the relationships should be accurate. The number of relationships should be adequate. That is, all of the important relationships should be shown on the map. ...
(slide 51, with relationships highlighted) (56)	The relationships on the photosynthesis concept map are marked in yellow. (5 second pause) While the relationships and general-to-specific hierarchy of a concept map are the most important features, concept maps may be judged in other ways. ...
(slide 51, with branches highlighted) (57)	Notice that the concepts "process", "chlorophyll", and "carbon dioxide" branch to several concepts that are placed lower on the map. ... The more upper-to-lower connections you can identify, the better the concept map...because it will be more meaningful. ...

(slide 51, with cross link highlighted) (58)	The photosynthesis concept map also shows a cross link ... between concepts located at the same level of the map. These cross-connections also make a concept map more meaningful. ...
SUMMARY (59)	This slide-tape program was intended to accomplish several objectives. ...
CONCEPTS (60)	What is a concept?...You should recall that a concept is a regularity in objects or events...that we identify with a label. People use concepts to organize their perceptions of the world around them. ...
MEANINGFUL LEARNING (slide 8) (61)	This program also described how people learn concepts. ... Humans learn unfamiliar concepts by linking them to concepts they already know. ...This process is called meaningful learning. ...
(slide 52) (62)	And finally, the concept mapping strategy was explained. You should understand...what a concept map is...how it can help you learn...and how to make one...Instructions and sample concept maps are included in your Concept Mapping Workbook and Instruction Manual. ...
(text, scissors, slips of paper, and manual) (63)	Refer to your manual when constructing the three maps that will be assigned in Natural Resources 201. ...Of course, you are encouraged to make additional maps and use them as study aids.
(Assignment sheet and pencil) (64)	Turn to the Assignment Sheet, which is the last page of the manual. ... Record the time it is now in the space provided . . . After turning in the slide-tape program, answer the questions, tear off the Assignment Sheet, and turn it in on the date indicated.
THE END (metal turtle and letters) (65)	This concludes the concept mapping module. Concept maps have a great potential to help people learn concepts meaningfully, and I hope you will find the strategy to be a useful one in your studies. ...

Name: ______________________________

CONCEPT MAPPING WORKBOOK AND INSTRUCTION MANUAL

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Read the directions section before you begin the slide-tape module.

Group 2

Directions

You have been randomly assigned to one of three concept mapping groups. The group number appears on the preceeding page.

All groups will complete the same assignments. The only difference will be that each group will learn and use a different version of the concept mapping strategy.

In order to help us determine which version should be used in future Natural Resources 201 classes, it is extremely important that you do not discuss concept mapping with other students. This will insure that students in each group will use only their assigned concept mapping strategy. Your cooperation will enable us to make the right decision.

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Wednesday 8:00am to 2:00pm
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Lower level, Pressey Hall, West Campus
Hours: M T W R 8:00am to 10:00pm
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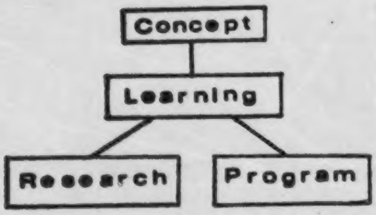
Saturday 10:00am to 5:00pm
Sunday 2:00pm to 10:00pm
*Obtain materials at the A-V Circulation Desk.

Bring this manual, a notebook and your OSU student ID with you. Although the slide-tape unit itself should last approximately one hour, allow an hour and a half total so that you have enough time to check out materials and set up the equipment.



Workbook

*** Make sure that the number on the slide-tape module ***
matches your group number.

INTRODUCTION

Obtain the slide tray and tape. After you have set up the equipment, write your name, group number and the time in the spaces provided on the Assignment Sheet (last page).

PART ONE: CONCEPTS, OBJECTS, AND EVENTS

Exercise 1

What do the objects have in common?

Exercise 2

What do the objects have in common?

Exercise 3

What do the events have in common?

Exercise 4

Below is a list of objects, events and concepts. Place an "O" beside objects, an "E" beside the events, and a "C" beside the concepts.

___ a. my car

___ b. Bob Hope's nose

___ c. your breathing at this moment

___ d. patriotism

___ e. World War II

___ f. deer

___ g. clock

___ h. biome

Turn the program back on when you complete this exercise.

PART TWO: MEANINGFUL LEARNING

(There are no exercises in this part of the program.)

PART THREE: CONCEPT MAPPING

Exercise 5

Read the paragraph below.

Metals are natural resources with which everyone is familiar. Metals occurring free from other materials are pure metals. Some pure metals such as gold, silver and platinum are called precious metals because they are rare. Copper, tin, iron, and zinc are considered common because they are more abundant. People have learned to combine pure metals with other substances to create new metals, called alloys. Steel, brass and bronze are alloys.

Exercise 6

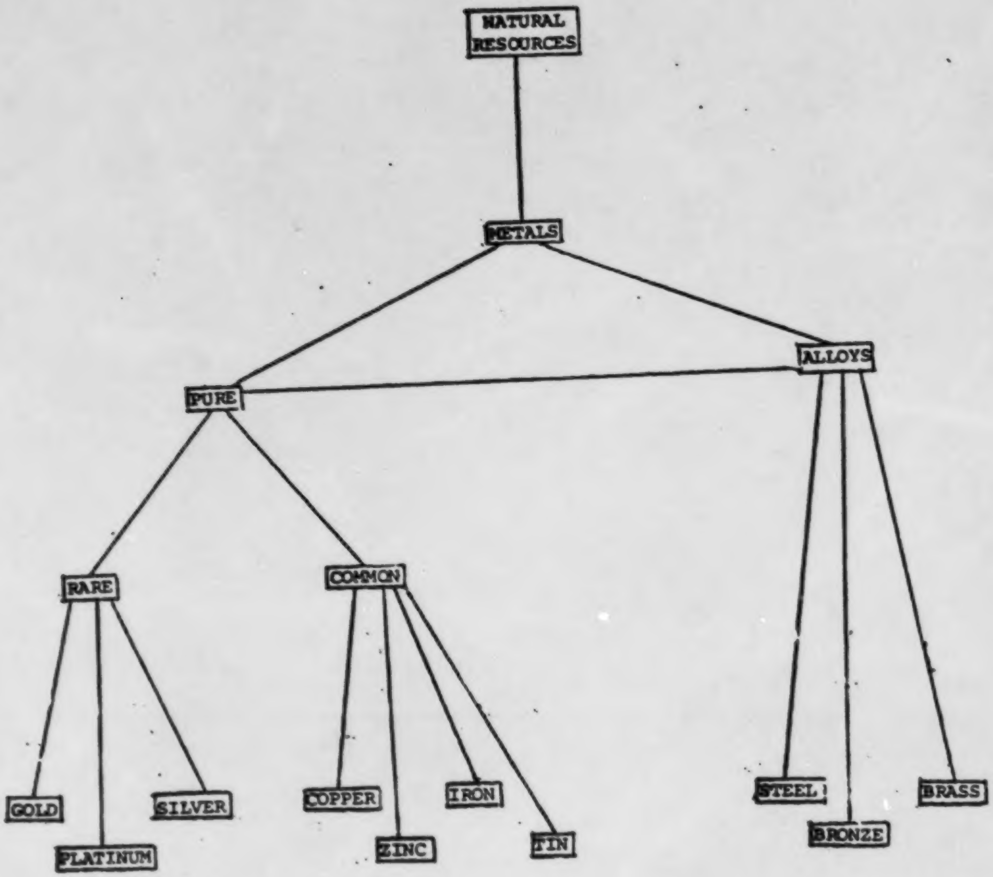
Question 1:

Question 2:

Question 3:

Question 4:

Question 5: platinum brass steel zinc tin


NATURAL RESOURCES
METALS
PURE
ALLOYS
RARE
COMMON
GOLD
PLATINUM
SILVER
COPPER
ZINC
IRON
TIN
STEEL
BRONZE
BRASS

EXAMPLE OF A CONCEPT MAP

Exercise 7

Make yourself about two dozen slips of paper 4" by 2½", if those provided with the learning materials have already been used up. Read the directions in the Instruction Manual, page 7 , for making a concept map.

Using these directions and the slips of paper, make a concept map from information presented in the paragraph below.

> Photosynthesis is a process by which plants utilize solar energy to convert carbon dioxide and water into sugar. The process can only occur if chlorophyll is present. Chlorophyll, a green plant pigment, serves as a catalyst for the photosynthesis reaction. In a sense, solar energy is "trapped" by chlorophyll and channeled into sugar molecules. The world's green plants fix 550 billion tons of carbon dioxide daily.
>
> — Adapted from Natural Resources Conservation (Owen, 1980, pp. 21-22).

When your concept map is completed, copy it onto a separate piece of paper. Turn the tape recorder and slide projector back on.

Instruction Manual

DIRECTIONS FOR CONSTRUCTING A CONCEPT MAP

1. Review the material presented or assigned.

2. Identify the concepts that appear most important. Write each of these on a small slip of paper.

3. Arrange the concept labels on a piece of paper from the most general (most inclusive) to the most specific (least inclusive). Put the most general concepts at the top of your paper, the most specific concepts at the bottom, and the concepts of intermediate importance somewhere in between.

4. Group concepts that are related to each other.

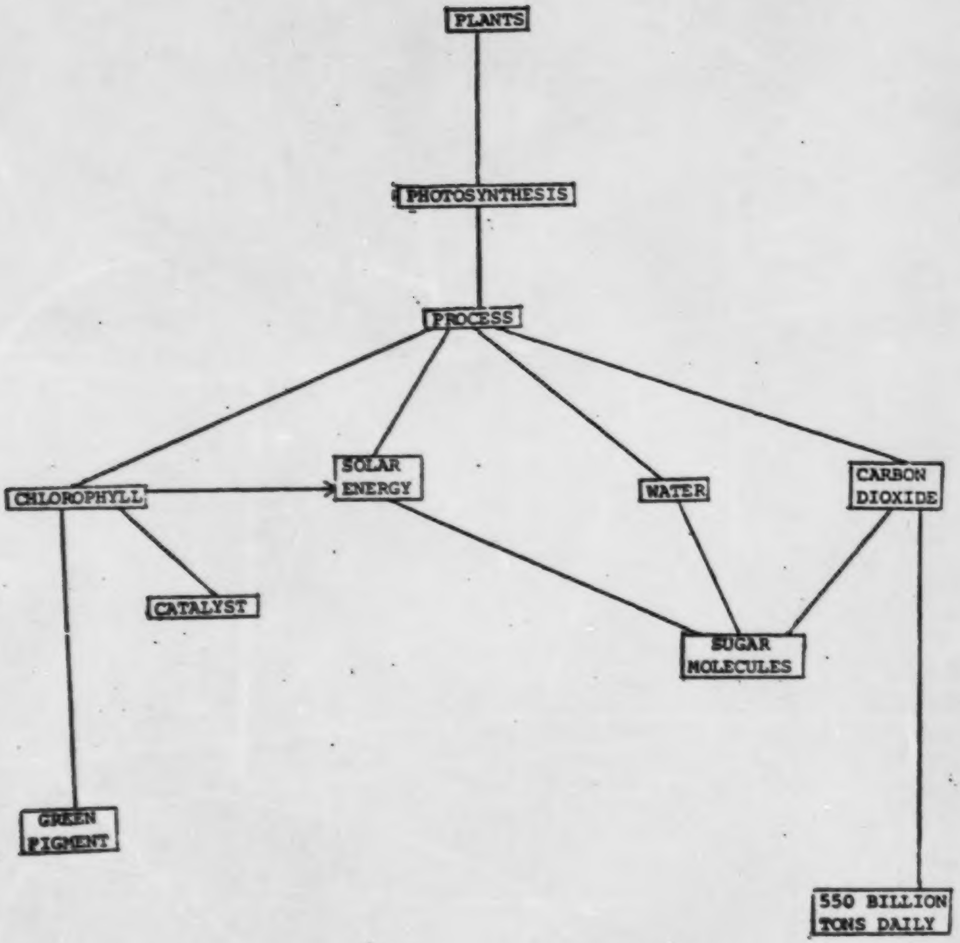
5. An example of a concept map is provided on the next page. Using this as a guide, show the relationships among the concepts in the material assigned. You will probably have to try several patterns of concepts and concept links before you find the organizational setup that makes the most sense to you.

6. Check your final arrangement against these criteria. A concept map should have the following features:

   a. Concepts are arranged in a hierarchy. That is, the map starts with the most general concepts at the top and proceeds down to the most specific concepts.

   b. Related concepts should be linked by lines (principles) that show these relationships. All important relationships should be shown.

7. Copy the completed concept map onto a separate piece of paper.


PLANTS
PHOTOSYNTHESIS
PROCESS
CHLOROPHYLL
SOLAR ENERGY
WATER
CARBON DIOXIDE
CATALYST
SUGAR MOLECULES
GREEN PIGMENT
550 BILLION TONS DAILY

CONCEPT MAP FOR PHOTOSYNTHESIS PARAGRAPH

Name: ______________________________

Assignment Sheet

Group #: __________

Time you began the slide-tape program: __________________

Time you finished the slide-tape program: __________________

Date you used the slide-tape program: __________________

Use your Instruction Manual and the information you learned during the slide-tape program to answer the following questions.

1. What is a concept?

2. How do concepts help people learn?

3. What features should a concept map have?

*** Due in class on Thursday, October 22 ***

CONCEPT MAPPING: A STRATEGY FOR LEARNING CONCEPTS

SCRIPT -- GROUP 3: P

Follow the HP script.(Group 1) for slide 1 through 41.

Slides	Narration
(metals concept map; same as workbook) (42)	What does the concept map do with the information that was presented previously in paragraph form?...How do you think a concept map might help you learn?...
CONCEPT MAPS... 1. IDENTIFY (43)	Concept maps have several features. First, they identify the concepts to be learned.
CONCEPT MAPS... 2. LINK 3. LABEL (44)	Second, the concepts that are related to each other are linked by lines. ... And finally, these linking lines are labelled with words that meaningfully relate the concepts to each other. ...
(concept map with concepts underlined in green) (45)	A concept map can be an effective learning strategy because it features concepts -- the mental "building blocks" that people think with. ...
(concept map with links underlined in green) (46)	In addition, a concept map shows how concepts are linked together. These linking lines have labels so that you can meaningfully -- not arbitrarily -- relate concepts to each other as you learn them. ...
(slide 42) (47)	Exercise 7 in your workbook involves you in making a concept map. Turn the tape recorder and slide projector off while completing the exercise. Once you are finished, turn the equipment back on. (10 second pause)
(slips of paper with concepts written on them) (48)	Let's take the concept mapping procedure step by step. The first step is to identify the concepts -- the regularities in objects or events -- described in the paragraph. These include photosynthesis, process, plants, solar energy, carbon dioxide, water, sugar molecules, chlorophyll, green pigment, and catalyst. It's surprising to see how many concepts can appear in a single paragraph! By writing each of these concepts on a small slip of paper, they can be easily organized.
(concept labels grouped) (49)	At this point, you should have grouped the concepts that are related to each other. For instance, both "catalyst" and "green pigment" describe the concept "chlorophyll", so the three concepts belong together.

... = pause

(concepts linked) (50)	The next step is to identify the principles -- these are linking words that verbally tie concepts to one another. ... For example, photosynthesis is a process that utilizes solar energy . ...
(completed concept map on photo-synthesis) (51)	Finally, you have to organize the concepts and principles into a completed map. ...This can be quite a juggling act. ...You will probably have to try several patterns of concepts and concept links before you find an organizational setup that means the most to you. ...In your Instruction Manual on page 8...is one of many possible maps that can be constructed from the photosynthesis paragraph. ...Since everyone assigns slightly different meanings to concepts, there is no one "correct" concept map. The best map is the one that is most meaningful to you.
CONCEPT MAP EVALUATION (52)	Some concept maps, however, are more complete than others. How can a concept map be evaluated?...
RELATIONSHIPS: *Accurate *Labeled *Adequate No. (53)	First, the relationships should be accurate and labeled properly. The number of relationships should be adequate. That is, all of the important relationships should be shown on the map. ...
(slide 51, with relationships highlighted) (54)	The relationships on the photosynthesis concept map are marked in yellow. ... While the relationships shown on a concept map are the most important features, concept maps may be judged in other ways. ...
(slide 51, with branches high-lighted) (55)	Notice that the concepts "carbon dioxide", "photosynthesis", and chlorophyll connect to several other concepts. The more concept connections you can identify, the better the concept map...because it will be more meaningful.
SUMMARY (56)	This slide-tape program was intended to accomplish several objectives. ...
CONCEPTS (slide 7) (57)	What is a concept?...You should recall that a concept is a regularity in objects or events...that we identify with a label. People use concepts to organize their perceptions of the world around them. ...
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(text, scissors, slips of paper, and manual) (60)	Refer to your manual when constructing the three maps that will be assigned in Natural Resources 201. ...Of course, you are encouraged to make additional maps and use them as study aids.
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THE END (metal turtle and letters) (62)	This concludes the concept mapping module. Concept maps have a great potential to help people learn concepts meaningfully, and I hope you will find the strategy to be a useful one in your studies. ...

Name: ______________________________

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Group 3

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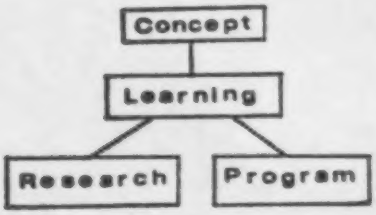
*Obtain materials at the A-V Circulation Desk.

Bring this manual, a notebook and your OSU student ID with you. Although the slide-tape unit itself should last approximately one hour, allow an hour and a half total so that you have enough time to check out materials and set up the equipment.



Workbook

*** Make sure that the number on the slide-tape module ***
matches your group number.

INTRODUCTION

Obtain the slide tray and tape. After you have set up the equipment, write your name, group number and the time in the spaces provided on the Assignment Sheet (last page).

PART ONE: CONCEPTS, OBJECTS, AND EVENTS

Exercise 1

What do the objects have in common?

Exercise 2

What do the objects have in common?

Exercise 3

What do the events have in common?

Exercise 4

Below is a list of objects, events and concepts. Place an "O" beside objects, an "E" beside the events, and a "C" beside the concepts.

___ a. my car

___ b. Bob Hope's nose

___ c. your breathing at this moment

___ d. patriotism

___ e. World War II

___ f. deer

___ g. clock

___ h. biome

Turn the program back on when you complete this exercise.

PART TWO: MEANINGFUL LEARNING

(There are no exercises in this part of the program.)

PART THREE: CONCEPT MAPPING

Exercise 5

Read the paragraph below.

> Metals are natural resources with which everyone is familiar. Metals occurring free from other materials are pure metals. Some pure metals such as gold, silver and platinum are called precious metals because they are rare. Copper, tin, iron, and zinc are considered common because they are more abundant. People have learned to combine pure metals with other substances to create new metals, called alloys. Steel, brass and bronze are alloys.

Exercise 6

Question 1:

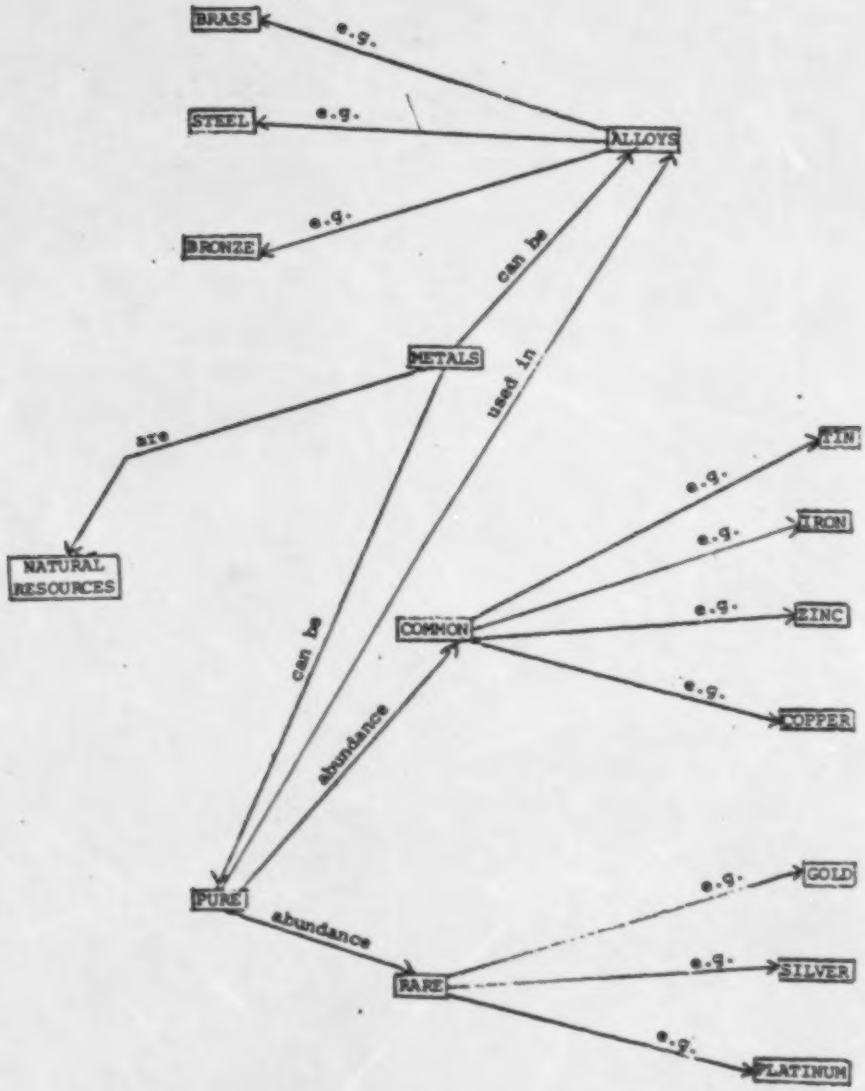
Question 2:

Question 3:

Question 4:

Question 5: platinum brass steel zinc tin

5


BRASS
e.g.
STEEL
e.g.
ALLOYS
BRONZE
e.g.
can be
METALS
used in
are
NATURAL RESOURCES
TIN
e.g.
IRON
e.g.
ZINC
e.g.
COMMON
e.g.
COPPER
can be
abundance
GOLD
e.g.
PURE
abundance
e.g.
SILVER
RARE
e.g.
PLATINUM

EXAMPLE OF A CONCEPT MAP

Exercise 7

Make yourself about two dozen slips of paper ½" by 2½", if those provided with the learning materials have already been used up. Read the directions in the Instruction Manual, page 7 , for making a concept map.

Using these directions and the slips of paper, make a concept map from information presented in the paragraph below.

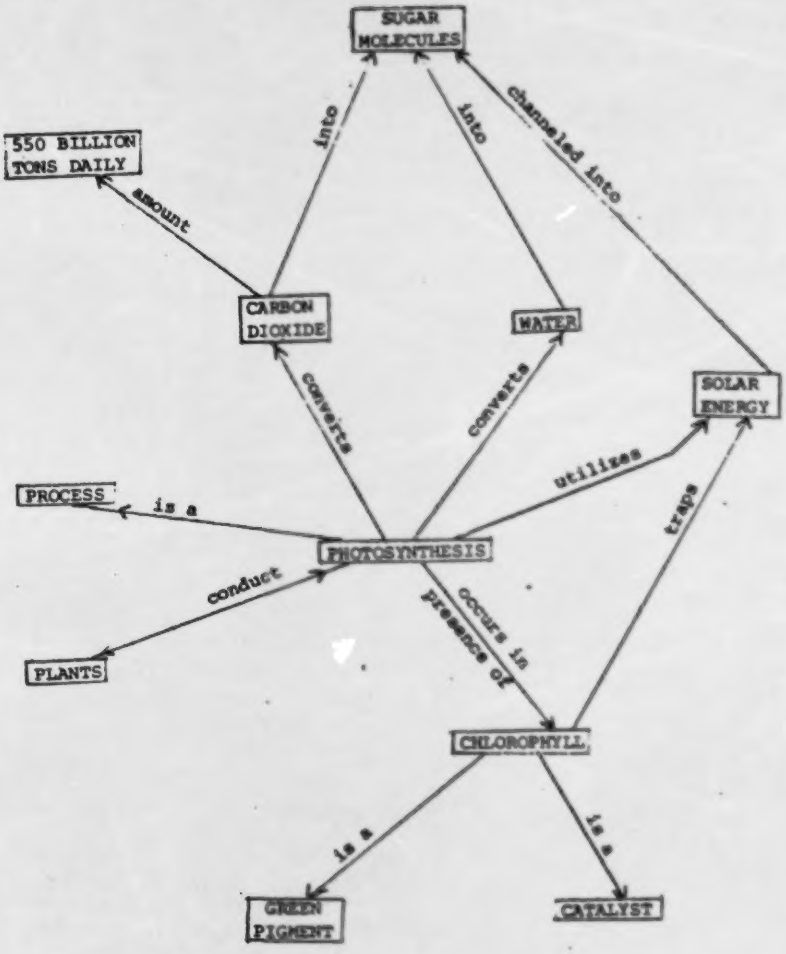
> Photosynthesis is a process by which plants utilize solar energy to convert carbon dioxide and water into sugar. The process can only occur if chlorophyll is present. Chlorophyll, a green plant pigment, serves as a catalyst for the photosynthesis reaction. In a sense, solar energy is "trapped" by chlorophyll and channeled into sugar molecules. The world's green plants fix 550 billion tons of carbon dioxide daily.
>
> — Adapted from Natural Resources Conservation (Owen, 1980, pp. 21-22).

When your concept map is completed, copy it onto a separate piece of paper. Turn the tape recorder and slide projector back on.

Instruction Manual

DIRECTIONS FOR CONSTRUCTING A CONCEPT MAP

1. Review the material presented or assigned.
2. Identify the concepts that appear most important. Write each of these on a small slip of paper.
3. Group concepts that are related to each other.
4. Identify a principle (word or phrase) that logically links each pair of concepts that are related to each other.
5. An example of a concept map is provided on the next page. Using this as a guide, show the relationships among the concepts in the material assigned. You will probably have to try several patterns of concepts and concept links before you find the organizational setup that makes the most sense to you.
6. Check your final arrangement against these criteria. A concept map should have the following features:
    - a. Related concepts should be linked by lines (principles) that show these relationships. All important relationships should be shown.
    - b. Each principle has a label that describes the relationship you use to link the concepts to each other. Labels should be accurate and specific.
    - c. An arrow on each linking line indicates which way to read the principle,
7. Copy the completed concept map onto a separate piece of paper.


SUGAR MOLECULES
550 BILLION TONS DAILY
amount
into
into
channeled into
CARBON DIOXIDE
WATER
SOLAR ENERGY
converts
converts
utilizes
PROCESS
is a
PHOTOSYNTHESIS
traps
conduct
PLANTS
occurs in presence of
CHLOROPHYLL
is a
is a
GREEN PIGMENT
CATALYST

CONCEPT MAP FOR PHOTOSYNTHESIS PARAGRAPH

Name: ______________________________

Assignment Sheet

Group #: __________

Time you began the slide-tape program: __________________

Time you finished the slide-tape program: ______________

Date you used the slide-tape program: ___________________

Use your Instruction Manual and the information you learned during the slide-tape program to answer the following questions.

1. What is a concept?

2. How do concepts help people learn?

3. What features should a concept map have?

*** Due in class on Thursday, October 22 ***

APPENDIX D

PREASSESSMENT OF BACKGROUND KNOWLEDGE

The 24 items used as the final instrument are circled, as are correct answers to the questions. Items 13 and 29 have two correct answers each.

Natural Resources 201

Concept Learning Research Program

ASSESSMENT OF BACKGROUND KNOWLEDGE

This test will examine your understanding of some basic concepts related to natural resources and their management. Your score on the test will not count toward your final grade in this course.

Indicate the best answer to each multiple-choice question on the answer sheet provided. If you do not know the answer and cannot make a reasonable, educated guess, mark choice "e", which is "don't know". This will provide us with an honest assessment of what NR 201 students already know, instead of showing us who the best guesser in the class is.

You will have approximately 30 minutes to complete this 30-item test.

1. Renewable resources are resources whose quantities can be maintained through reproduction, growth and management. Which of the following is a renewable resource?

   a. coal
   b. air
   c. sunlight
   [✓ d.] wildlife
   e. don't know

2. Coal, oil and natural gas are all products of:

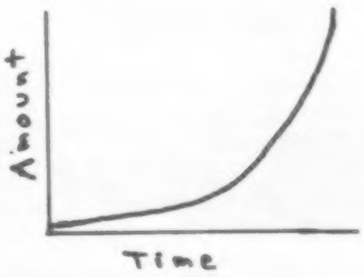
   a. volcanic activity
   b. ocean deposits
   c. the earth's heat
   [✓ d.] decaying vegetation
   e. don't know

3. Ohio's forests are located primarily in the _________ region of the state.

   a. Lake Erie
   b. southeastern
   c. western
   d. central
   e. don't know

4. Examine the graph to the right. Which of the following would not conform to such a curve?

   a. population
   b. food production
   c. pollution
   [✓ d.] resource supply
   e. don't know



5. What system of electrical generation by wind power or solar energy would be most acceptable to the electric utilities?

   a. a decentralized system, so no single utility could control it
   b. home-based systems, since they are not efficient enough to threaten utility profits
   c. a system under which homeowners could sell the electricity they produce to the utilities
   [✓ d.] a centralized system, so utilities could meter electricity to their customers
   e. don't know

6. The rate at which soil is formed from bedrock, and the kind of soil that is formed in a given area, are due to many factors. Which of the following factors would have the least effect upon soil formation?

a. climate
b. topography
c. living organisms
[✓ d. longitude]
e. don't know

7. Energy "flows" through the environment. That is, it is being constantly transferred from one place or from one organism to another. When energy is transferred:

a. additional energy is produced
[✓ b. much usable energy is lost]
c. all the energy is transferred
d. energy flows in two directions
e. don't know

8. The factor most responsible for accelerating the world's rate of human population growth is:

[✓ a. decreasing death rate]
b. greater migration between countries
c. increasing birth rate
d. more births per female
e. don't know

9. Wildlife in Ohio is owned by:

[✓ a. citizens of the state]
b. private landowners
c. the League of Ohio Sportsmen
d. the Ohio Department of Natural Resources
e. don't know

10. Nations in transition from an agricultural to an industrial society most frequently experience:

[✓ a. a rapid growth in human population]
b. a lowering of the human birth rate
c. large increases in the human death rate
d. population decreases because people leave the country
e. don't know

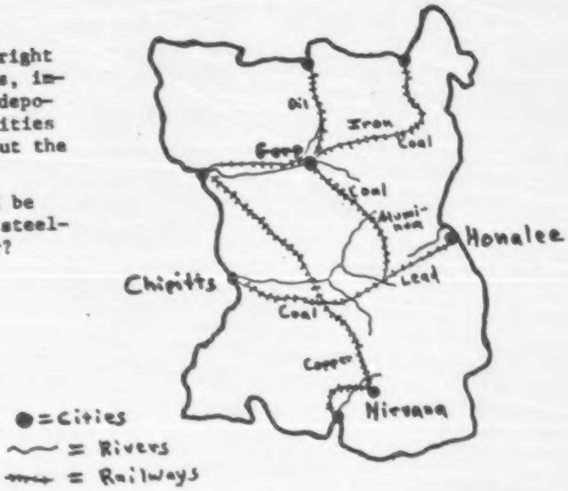
11. The utilization of ocean resources has increased largely because of:

[✓ a. advances in technology]
b. United Nations programs
c. strong political leadership
d. world conferences on sea laws
e. don't know

12. Pictured to the right are the railroads, important mineral deposits and major cities of an island about the size of Texas.

Which city would be the most likely steel-producing center?

a. Honalee
b. Nirvana
[✓ c.] Gorp
d. Chipitts
e. don't know



13. Nonrenewable resources are those resources that are not reformed or regenerated in nature at rates equal to the rates at which people use them. Which of the following is a nonrenewable resource?

a. wood
[✓ b.] water
c. animals
[✓ d.] petroleum
e. don't know

14. The best long-term method of maintaining and/or increasing a wildlife population is to:

a. eliminate hunting
b. eliminate diseases and predators
[✓ c.] create or maintain suitable habitats
d. bring in food when food is scarce
e. don't know

15. A natural resources economist would find it easiest to assign a dollar value to:

a. genetic damage to Hiroshima residents following the A-bomb
b. unsightliness of highway billboards
c. annoyance of airplanes flying over an elementary school
[✓ d.] crop damage resulting from air pollution
e. don't know

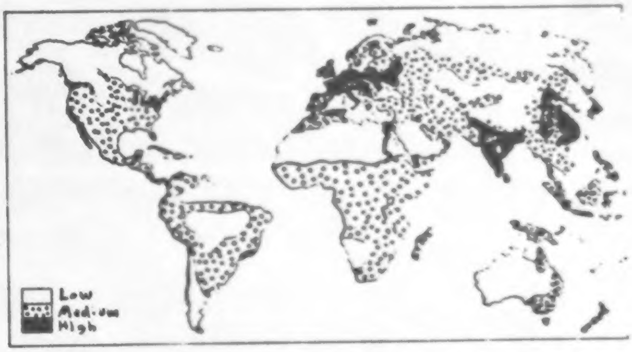
16. The demand for recreation in a given country is determined primarily by the country's:

a. population size
b. size of land area
c. variety of recreation opportunities
[✓ d.] standard of living
e. don't know

17. Most objections to the use of nuclear power in the U.S. are in regard to which of these issues?

    a. whether or not there is a need for more electricity
    b. the vulverability of nuclear plants to earthquakes
    c. locating nuclear plants near human settlements
    d. the possibility that nuclear material would be used for atomic weapons production
    e. don't know

18.



The shading on the map above indicates:

    a. population density
    b. percentage of total labor force in agriculture
    c. death rate per thousand of population
    d. standard of living
    e. don't know

19. Which of the following wildlife species is more abundant in the U.S. today than it was in the 1700's?

    a. wild turkey
    [✓ b.] deer
    c. beaver
    d. wolf
    e. don't know

20. Which fuel source listed below causes the least pollution when burned?

    a. coal
    b. oil
    [✓ c.] natural gas
    d. wood
    e. don't know

21. Wildlife managers often study the influence of factors which limit the number of animals that can live in a given area. These factors fall into two categories:
    1. factors whose influence depends on the number of animals living in a given area (density dependent)
    2. factors whose influence does not depend on the number of animals living in a given area (density independent)

    Which of the following factors belongs in category #2?

    - a. starvation
    - [✓ b.] forest fires
    - c. disease
    - d. predation
    - e. don't know

22. Recreation may be defined as a leisure experience involving a personal choice of activities which lead to immediate rewards or satisfactions. All of the following activities could be classified as recreation except:

    - a. vandalizing a park sign for fun
    - b. going to a football game
    - c. watching cartoons
    - [✓ d.] taking a required physical education course
    - e. don't know

23. The greatest threats to wildlife populations are:

    - a. predators
    - [✓ b.] land use changes
    - c. parasites and diseases
    - d. hunters
    - e. don't know

24. Which group of living organisms has the greatest amount of energy available to it?

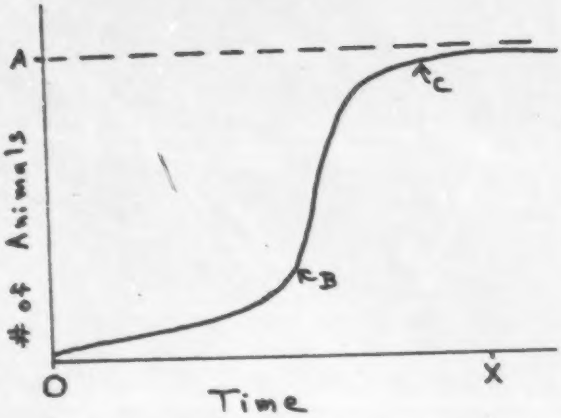
    - [✓ a.] green plants
    - b. meat-eating animals
    - c. plant-eating animals
    - d. decay organisms
    - e. don't know

25. The source of energy for most electric power in Ohio is:

    - a. oil
    - [✓ b.] coal
    - c. nuclear
    - d. natural gas
    - e. don't know

The next three questions refer to the graph at the right.

The growth rate of a group of animals of one species living in a given area usually conforms to the pattern depicted in this graph. Assume the time span from "0" to "X" is about a dozen years.



26. The dashed line "A" represents:

   a. the average number of animals found in the area at any one time
   b. the time required for the number of animals to reach the maximum level
   [✓ c.] the maximum number of animals that the area can support
   d. the maximum growth rate of the animal group living in the area.
   e. don't know

27. The main reason why the steep slope at point "B" on the curve occurred is because:

   a. more young are born at this time
   b. plenty of resources are available to animals living in the area
   c. forest fires, floods and other natural disasters have not occurred
   d. hunting was not permitted
   e. don't know

28. At point "C", the curve has nearly leveled off. One reason for this is:

   [✓ a.] there are not enough resources for any more animals to live in the area
   b. young animals are unlikely to reproduce immediately
   c. the mating season has ended
   d. the animals are so widely dispersed that they are unlikely to find each other and mate
   e. don't know

29. Inexhaustible resources are resources which humans cannot use up. Which of the following is an inexhaustible resource?

[✓ a.] water
b. natural gas
[✓ c.] copper
d. wood
e. don't know

30. Some resources required by living things are cyclic; that is, they are used over and over again. Other resources are linear; once they are used, they're no longer available. Which of the following resources is linear?

a. oxygen
b. solar energy
c. nitrogen
d. soil
e. don't know

END OF TEST

Make sure that all of your answers are marked
on the answer sheet.

Concept
Learning
Research Program

APPENDIX E

BACKGROUND QUESTIONNAIRE AND TEST OF LOGICAL THINKING

Name ______________________

Natural Resources 201

Concept Learning Research Program

QUESTIONNAIRE AND TEST OF LOGICAL THINKING

In order to interpret the results of the Concept Learning Research Program, some general background information is needed on students who are taking NR 201 this quarter.

The course questionnaire appears below, and the Test of Logical Thinking beings on the next page. Be sure to use the special answer sheet (next page) for the Test of Logical Thinking.

Please fill out both the questionnaire and the logical thinking test carefully. Your answers to the questions and the test items will not, in any way, affect your final grade in this course. All that is required is that you complete the two forms.

* * * * * * * * * * * * * * * * * * *

Sex: __________ Birth Date: ______________________________
(month) (day) (year)

Major: ______________________ Rank: Frosh Soph Junior Senior

Previous course work related to Natural Resources 201:
(List both title of course and course #, if known)

Botany/Zoology/Biology:

Natural Resources:

Economics/Sociology:

Other relevant courses:

*** DUE IN CLASS ON TUESDAY, SEPTEMBER 29 ***

ANSWER SHEET *

FORM A

Name ______________________

DIRECTIONS

A series of eight problems is presented. Each problem will lead to a question. Record the answer you have chosen and reason for selecting that answer.

Problem	**Best Answer**	**Reason**
1. Orange Juice #1	________	_____
2. Orange Juice #2	________	_____
3. The Pendulum's Length	________	_____
4. The Pendulum's Weight	________	_____
5. The Vegetable Seeds	________	_____
6. The Flower Seeds	________	_____
7. The Mice	________	_____
8. The Fish	________	_____

Put your answers to quescions 9 and 10 below:

The Student Council

9. TJD SAM _____ _____

The Shopping Center

10. BDGC _____ _____ _____

---

* Test of Logical Thinking (TOLT), by William Capie and Kenneth G. Tobin.

Orange Juice #1

Item 1

Four large oranges are squeezed to make six glasses of juice. How much juice can be made from six large oranges?

a. 7 glasses
b. 8 glasses
c. 9 glasses
d. 10 glasses
e. other

Reason

1. The number of glasses compared to the number of oranges will always be in the ratio 3 to 2.
2. With more oranges, the difference will be less.
3. The difference in the numbers will always be two.
4. With four oranges the difference was 2. With six oranges the difference would be two more.
5. There is no way of predicting.

Orange Juice #2

Item 2

How many oranges are needed to make 13 glasses of juice?

a. 6½ oranges
b. 8 2/3 oranges
c. 9 oranges
d. 11 oranges
e. other

Reason

1. The number of oranges compared to the number of glasses will always be in the ratio 2 to 3.

2. If there are seven more glasses, then five more oranges are needed.

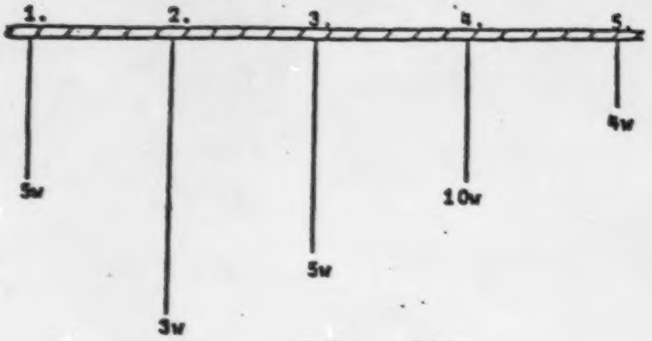
3. The difference in the numbers will always be two.

4. The number of oranges will be half the number of glasses.

5. There is no way of predicting the number of oranges.

The Pendulum's Length

Item 3



Suppose you wanted to do an experiment to find out if changing the length of a pendulum changed the amount of time it takes to swing back and forth. Which pendulums would you use for the experiment?

a. 1 and 4

b. 2 and 4

c. 1 and 3

d. 2 and 5

e. all

Reason

1. The longest pendulum should be tested against the shortest pendulum.

2. All pendulums need to be tested against one another.

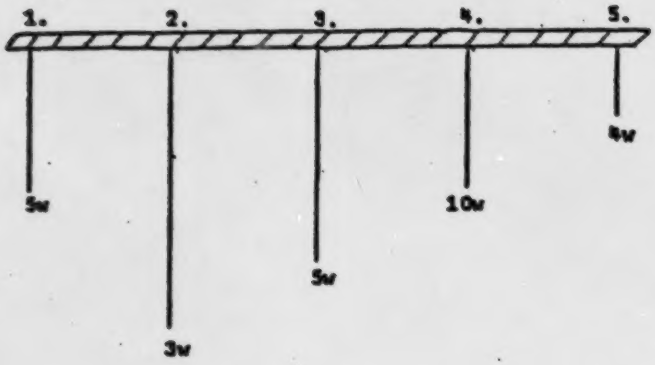
3. As the length is increased the number of washers should be decreased.

4. The pendulums should be the same length but the number of washers should be different.

5. The pendulums should be different lengths but the number of washers should be the same.

The Pendulum's Weight

Item 4



Suppose you wanted to do an experiment to find out if changing the weight on the end of the string changed the amount of time the pendulum takes to swing back and forth. Which pendulums would you use for the experiment?

a. 1 and 4

b. 2 and 4

c. 1 and 3

d. 2 and 5

e. all

__Reason__

1. The heaviest weight should be compared to the lightest weight.
2. All pendulums need to be tested against one another.
3. As the number of washers is increased the pendulum should be shortened.
4. The number of washers should be different but the pendulums should be the same length.
5. The number of washers should be the same but the pendulums should be different lengths.

The Vegetable Seeds

Item 5

A gardener bought a package containing 3 squash seeds and 3 bean seeds. If just one seed is selected from the package what are the chances that it is a bean seed?

a. 1 out of 2

b. 1 out of 3

c. 1 out of 4

d. 1 out of 6

e. 4 out of 6

Reason

1. Four selections are needed because the three squash seeds could have been chosen in a row.
2. There are six seeds from which one bean seed must be chosen.
3. One bean seed needs to be selected from a total of three.
4. One half of the seeds are bean seeds.
5. In addition to a bean seed, three squash seeds could be selected from a total of six.

The Flower Seeds

Item 6

A gardener bought a package of 21 mixed seeds. The package contents listed:

3 short red flowers
4 short yellow flowers
5 short orange flowers
4 tall red flowers
2 tall yellow flowers
3 tall orange flowers

If just one seed is planted, what are the chances that the plant that grows will have red flowers?

a. 1 out of 2

b. 1 out of 3

c. 1 out of 7

d. 1 out of 21

e. other

Reason

1. One seed has to be chosen from among those that grow red, yellow or orange flowers.
2. 1/4 of the short and 4/9 of the talls are red.
3. It does not matter whether a tall or a short is picked. One red seed needs to be picked from a total of seven red seeds.
4. One red seed must be selected from a total of 21 seeds.
5. Seven of the twnety-one seeds will produce red flowers.

The Mice

Item 7

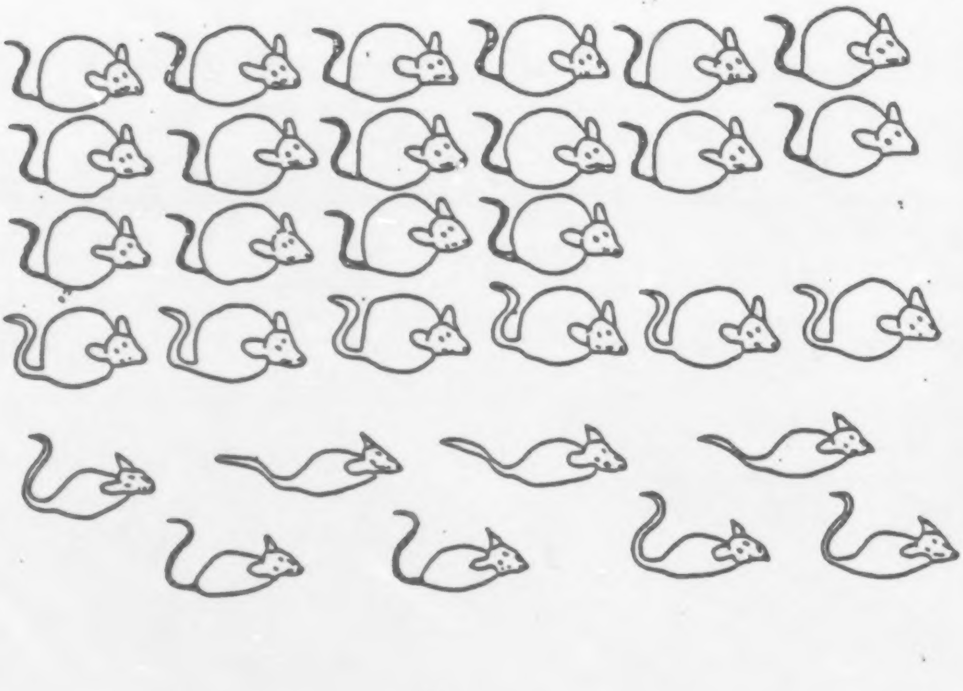
The mice shown represent a sample of mice captured from a part of a field. Are fat mice more likely to have black tails and thin mice more likely to have white tails?

a. Yes

b. No

Reason

1. 8/11 of the fat mice have black tails and 3/4 of the thin mice have white tails.
2. Some of the fat mice have white tails and some of the thin mice have white tails.
3. 18 mice out of 30 have black tails and 12 have white tails.
4. Not all of the fat mice have black tails and not all of the thin mice have white tails.
5. 6/12 of the white tailed mice are fat.



The Fish

Item 8

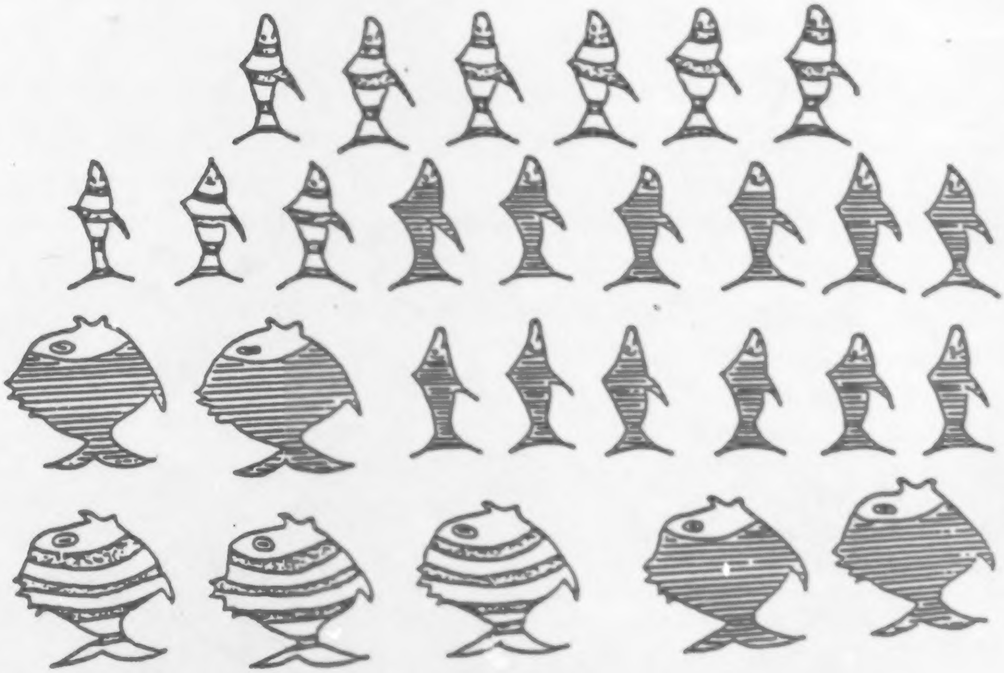
Are fat fish more likely to have broad stripes than thin fish?

a. Yes

b. No

Reason

1. Some fat fish have broad stripes and some have narrow stripes.
2. 3/7 of the fat fish have broad stripes.
3. 12/28 are broad striped and 16/28 are narrow striped.
4. 3/7 of the fat fish have broad stripes and 9/21 of the thin fish have broad stripes.
5. Some fish with broad stripes are thin and some are fat.



The Student Council

Item 9

Three students from grades 10, 11, 12 were elected to the student council. A three member committee is to be formed with one person from each grade. All possible combinations must be considered before a decision can be made. Two possible combinations are Tom, Jerry and Dan (TJD) and Sally, Anne and Martha (SAM). List all other possible combinations in the space provided.

More spaces are provided on the Answer Sheet than you will need.

STUDENT COUNCIL

Grade 10	Grade 11	Grade 12
Tom (T)	Jerry (J)	Dan (D)
Sally (S)	Anne (A)	Martha (M)
Bill (B)	Connie (C)	Gwen (G)

The Shopping Center

Item 10

In a new Shopping Center, 4 store locations are going to be opened on the ground level.

A BARBER SHOP (B), a DISCOUNT STORE (D), a GROCERY STORE (G), and a COFFEE SHOP (C) want to move in there. Each one of the stores can choose any one of four locations. One way that the stores could occupy the 4 locations is BDGC. List all other possible ways that the stores can occupy the 4 locations.

More spaces are provided on the Answer Sheet than you will need.

END OF TEST

Make sure that all of your answers are marked
on the answer sheet.

APPENDIX F

CONCEPT MAPPING SCORING PROCEDURES

Tally sheets used to score students' maps are presented.

Student #: ____________

Concept Map #: ____________

CONCEPT MAP SCORE SHEET

HIERARCHICAL-PROPOSITIONAL CONCEPT MAPS (Group #1)

Required concepts mapped	% of master map	Total concepts mapped	
___	___	___	**Relationships** 1 point for each correct and explicitly stated relationship.
___	___	___	**Hierarchy** 1 point per level, up until 2 levels beyond last branching if map remains linear.
___	___	___	**Branching** 1 point for first branching; 3 points for each additional branching. Relationships must be correct.
___	___	___	**Cross Links** 2 points for each correct link between branches.
___	___	___	**TOTAL CONCEPT MAP SCORES**

Student #: ____________

Concept Map #: ____________

CONCEPT MAP SCORE SHEET

HIERARCHICAL CONCEPT MAPS (Group #2)

Required concepts mapped	% of master map	Total concepts mapped	
___	___	___	**Relationships** 1 point for each concept link present.
___	___	___	**Hierarchy** 1 point per level, up until 2 levels beyond last branching if map remains linear.
___	___	___	**Branching** 1 point for first branching; 3 points for each additional branching.
___	___	___	**Cross Links** 2 points for each link between branches.
___	___	___	**TOTAL CONCEPT MAP SCORES**

Student #: ____________

Concept Map #: ____________

CONCEPT MAP SCORE SHEET

PROPOSITIONAL CONCEPT MAPS (Group #3)

Required concepts mapped	% of master map	Total concepts mapped	
___	___	___	**Relationships** 1 point for each correct and explicitly stated relationship.
___	___	___	**Branching** 1 point for first branching (= 2 links from 1 concept); 3 points for each additional branching. Relationships must be correct.
___	___	___	**Cross Links** 1 point for each correct link between branches (= 2 links to 1 concept).
___	___	___	**TOTAL CONCEPT MAP SCORES**

APPENDIX G

EXAMPLES OF STUDENT-CONSTRUCTED CONCEPT MAPS

The concept mapping assignment is followed by the tally sheet and then a copy of the student's map. Only assigned concepts on the map were scored; the others were ignored.

Natural Resources 201
Concept Learning Research Program

ASSIGNMENT: CONCEPT MAP 1

Review Chapters 17 (The Energy Crisis) and 18 (Nuclear Energy, Radiation, and Man). In addition, review your notes from the lectures on energy resources presented in class on October 20, 22 and 23.

Using the directions provided in your Concept Mapping Workbook and Instruction Manual, make a concept map that includes all of these concepts:

- Availability
- Biomass
- Coal
- Demand
- Energy Resources
- Fossil Fuels
- Inexhaustible
- Level of Living
- Nonrenewable
- Population Size
- Renewable
- Solar
- Supply
- Tar Sands
- Uranium
- Wood

Feel free to add any other concepts which will make the map more meaningful to you. Draw your completed map on a separate sheet of paper, and turn it in on the date listed below. Please write darkly, so that a photocopy of your map may be made and returned to you.

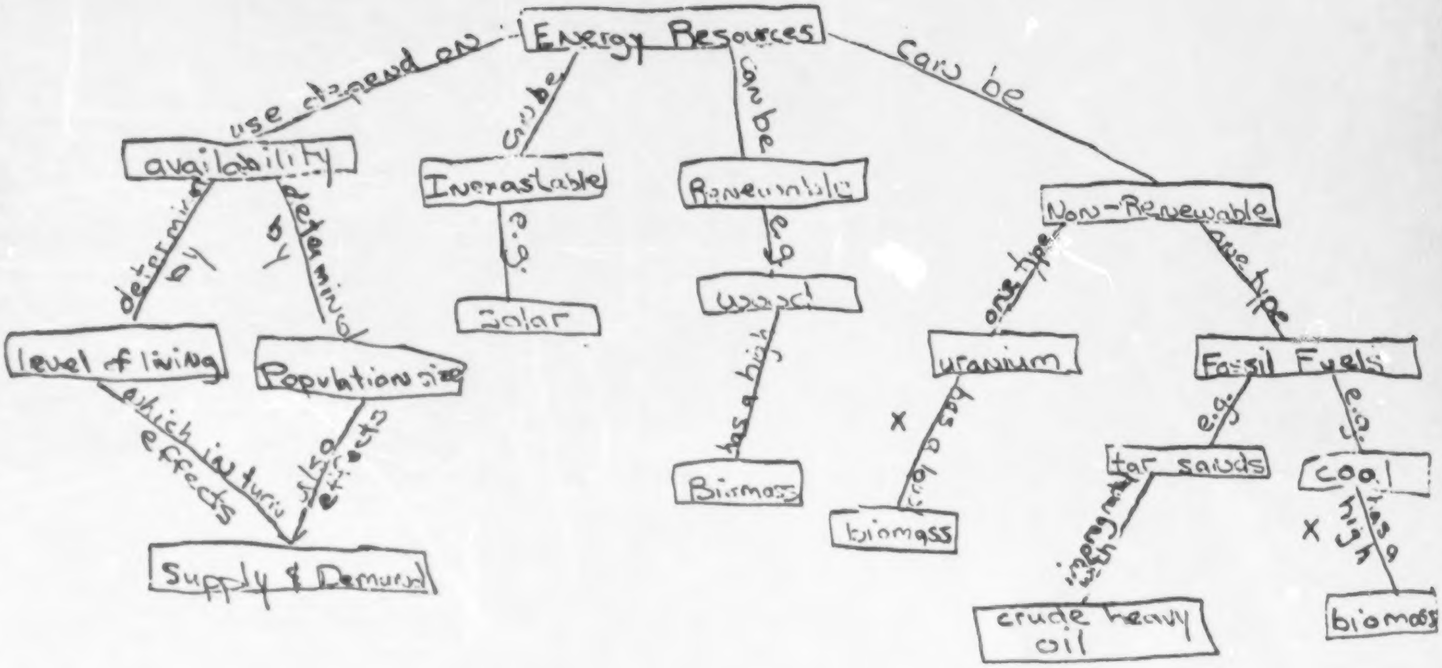
*** Due in class on Thursday, October 29 ***
Include your name and group number on your assignment.

Student #: 080
Concept Map #: 1

CONCEPT MAP SCORE SHEET

HIERARCHICAL-PROPOSITIONAL CONCEPT MAPS (Group #1)

Required concepts mapped	% of master map	Total concepts mapped	
15		16	**Relationships** 1 point for each correct and explicitly stated relationship.
4		4	**Hierarchy** 1 point per level, up until 2 levels beyond last branching if map remains linear.
10		10	**Branching** 1 point for first branching; 3 points for each additional branching. Relationships must be correct.
2		2	**Cross Links** 2 points for each correct link between branches.
31		32	**TOTAL CONCEPT MAP SCORES**


Energy Resources
use depend on
availability
determine by
determine by
level of living
Population size
which in turn effects
also effects
Supply & Demand
can be
Inexastable
e.g.
Solar
can be
Renewable
e.g.
wood
has a high
Biomass
can be
Non-Renewable
one type
uranium
X
has a low
biomass
one type
Fossil Fuels
e.g.
tar sands
impregnated with
crude heavy oil
e.g.
coal
X
has a high
biomass

Natural Resources 201
Concept Learning Research Program

ASSIGNMENT: CONCEPT MAP 2

Review your notes and handouts from the lecture on ecological concepts (September 29) and the lecture on wildlife management (October 30). In addition, reread pages 23-24, 39-45, 330-332, and 341-356 in Owen's Natural Resource Conservation.

Using the directions provided in your Concept Mapping Workbook and Instruction Manual, make a concept map that includes all of these concepts:

- Abiotic Components
- Air
- Animals
- Biotic Components
- Biotic Potential
- Carrying Capacity
- Ecosystems
- Environmental Resistance
- Habitats
- Optimum Yield (Harvest)
- Overproduction
- Plants
- Population Size
- Sunlight
- Water

Feel free to add any other concepts which will make the map more meaningful to you. Draw your completed map on a separate sheet of paper, and turn it in on the date listed below. Please write darkly, so that a photocopy of your map may be made and returned to you.

*** Due in class on Thursday, November 5 ***

Include your name, group number,
and an estimate of the time required to complete the assignment.

Student #: 092

Concept Map #: 2

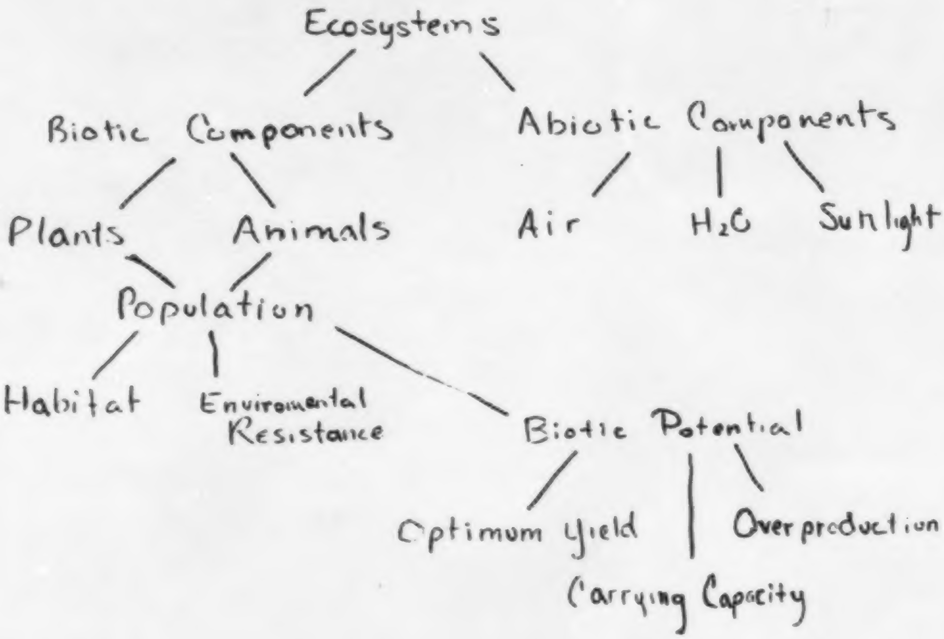
CONCEPT MAP SCORE SHEET

HIERARCHICAL CONCEPT MAPS (Group #2)

Required concepts mapped	% of master map	Total concepts mapped	
15		15	Relationships 1 point for each concept link present.
5		5	Hierarchy 1 point per level, up until 2 levels beyond last branching if map remains linear.
13		13	Branching 1 point for first branching; 3 points for each additional branching.
2		2	Cross Links 2 points for each link between branches.
35		35	TOTAL CONCEPT MAP SCORES

Concept Map 2
Nov. 5, 1981

Group 2


Ecosystems
Biotic Components
Abiotic Components
Plants
Animals
Air
H_2O
Sunlight
Population
Habitat
Enviromental Resistance
Biotic Potential
Optimum Yield
Carrying Capacity
Overproduction

Natural Resources 201

Concept Learning Research Program

ASSIGNMENT: CONCEPT MAP 3

Review your notes, the handout and the supplemental reading ("Economics: A Part of Environmental Management") from the lecture on the role of economics in natural resources management.

Using the directions provided in your Concept Mapping Workbook and Instruction Manual, make a concept map that includes all of these concepts:

Abatement
Avoidance
Benefits
Costs
Development
Economics
Efficiency
Equity
Monetary Effects
Natural Resources Management
Nonmonetary Effects
Opportunity
Political Process
Societal Goals
Tradeoff Tables
Transaction

Feel free to add any other concepts which will make the map more meaningful to you. Draw your completed map on a separate sheet of paper, and turn it in on the date listed below. Please write darkly, so that a photocopy of your map may be made and returned to you.

*** Due in class on Tuesday, November 17 ***

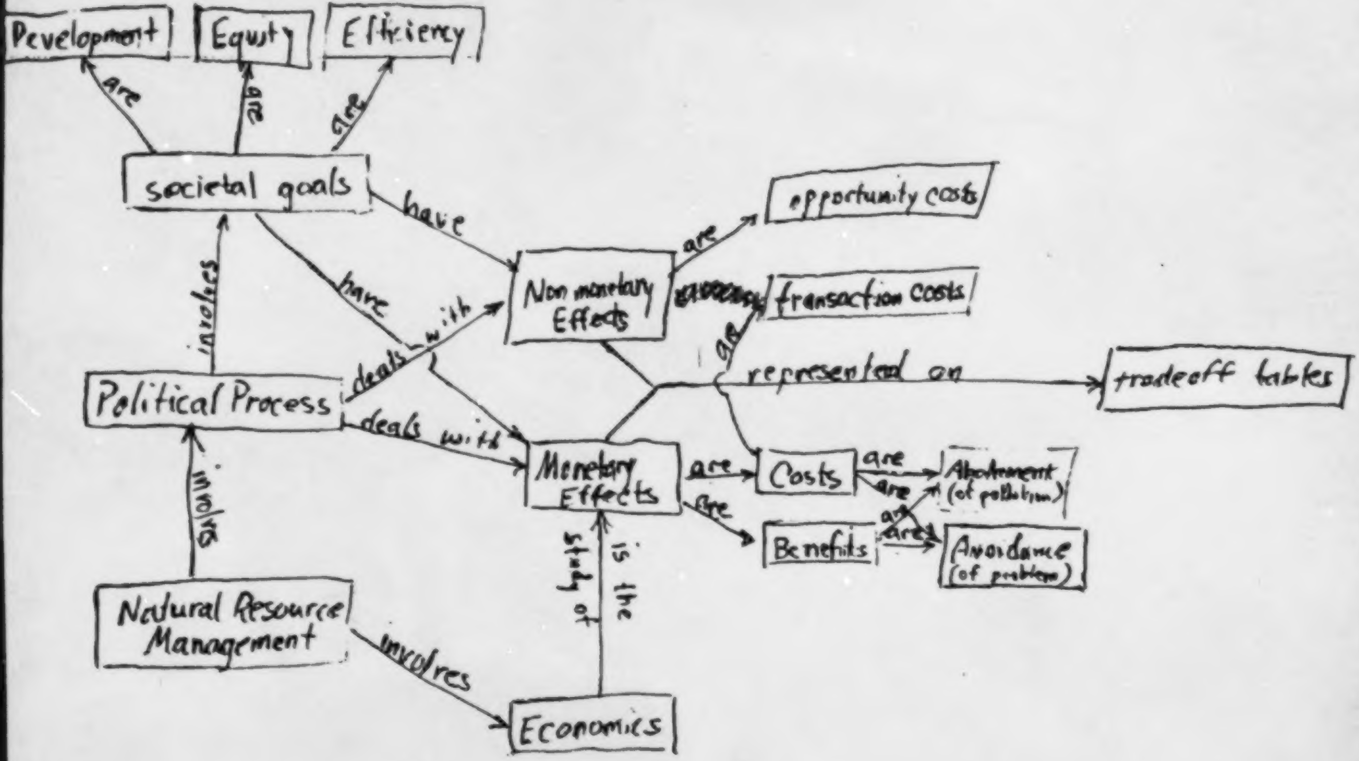
Include your name, group number,
and an estimate of the time required to complete the assignment.

Student #: 063
Concept Map #: 3

CONCEPT MAP SCORE SHEET

PROPOSITIONAL CONCEPT MAPS (Group #3)

Required concepts mapped	% of master map	Total concepts mapped	
21		21	**Relationships** 1 point for each correct and explicitly stated relationship.
10		10	**Branching** 1 point for first branching (= 2 links *from* 1 concept); 3 points for each additional branching. Relationships must be correct.
12		12	**Cross Links** 2 point for each correct link between branches (= 2 links *to* 1 concept).
43		43	**TOTAL CONCEPT MAP SCORES**


Development
Equity
Efficiency
are
are
are
societal goals
have
have
opportunity costs
are
Non monetary Effects
transaction costs
are
involves
deals with
represented on
tradeoff tables
Political Process
deals with
Monetary Effects
are
Costs
are
are
Abatement (of pollution)
are
are
are
Benefits
Avoidance (of problems)
involves
is the study of
Natural Resource Management
involves
Economics

APPENDIX H

NATURAL RESOURCES CONCEPTS POSTTEST

Answers to the 24 items that comprise the Natural Resources Concepts Posttest are circled. Each question is also keyed to the appropriate posttest subscales:

M = Mapped Concepts Subscale

U = Unmapped Concepts Subscale

En = Energy Resources Subscale

We = Wildlife Ecology Subscale

Ec = Resource Economics Subscale

NR 201
Final Exam
Autumn 1981

Use the computerized form as an answer sheet. Please use pencil and be sure to completely fill in the space corresponding to the letter of the answer you have chosen.

On your answer sheet fill in:

- *your name, last name first
- *your three number test code from the top corner of your answer sheet. Put this in the last 3 columns where it asks for your name.
- *your identification number (Social Security No.)
- *your test code. Fill in "0" if you are using the white form and "1" if you are using the blue form of the test.

Read each question CAREFULLY. Fill in the letter of the BEST answer on your answer sheet. Be sure to fill in only one answer for each question. ERASE all stray marks completely! Each question is worth two points. Good luck!

1. The basic source of energy for the biotic communities of the world is:

U,E.

   a. fossil fuels.
   b. green plants.
   c. nuclear fission.
   [✓ d.] the sun.

2. According to Professor Touse, the area of the U.S. that is most involved in monoculture timber production is the:

   a. Northeast.
   b. South.
   c. Southwest.
   d. West.

3. Which of the following is an abiotic resource that is renewable?

   a. natural gas
   b. manganese nodules
   c. whitetail deer
   d. solar energy

4. The major tool of wildlife managers to manipulate population is to control:

   a. disease.
   b. predation.
   c. sport hunting.
   d. vegetation.

5. The most economically valuable biological communities are found in:

   a. grasslands.
   b. estuaries.
   c. the open ocean.
   d. tropical rain forests.

6. All of the following are examples of structural adaptions EXCEPT:

   a. large leaves.
   b. feathers on legs.
   c. white fur.
   d. burrowing in the ground.

7. Timber cannot be harvested in a National Park. What kind of cost results from this policy?

U, Ec

   a. avoidance
   b. development
   [✓ c.] opportunity
   d. transaction

8. Which statement best describes how the terms carrying capacity and population size are related?

M, We

   [✓ a.] A given species' population size is determined by the habitat's carrying capacity.
   b. The population size of a species determines the carrying capacity of the habitat.
   c. The population size of a given species at any time is a good measure of the habitat's carrying capacity.
   d. The carrying capacity of a habitat is a good measure of a given species' present population size.

9. According to Dr. Douglass, during bad economic times participation in leisure activities:

   a. increases overall.
   b. decreases overall.
   c. switches to high risk activities.
   d. shifts to low risk activities.

10. According to Dr. Shepard, the major factor in determining land use in the U.S. has been:

   a. economics.
   b. sociology.
   c. environmental concern.
   d. politics.

11. A farmer has severe soil erosion on his property because of poor soil management techniques. Can the federal Soil Conservation Agent intervene?

   a. Yes, using the power of eminent domain.
   b. Yes, because of escheat power.
   c. No, because the farmer has less than fee simple ownership.
   d. No, because the farmer has fee simple rights.

12. All of the following are part of the technical definition of hazardous wastes EXCEPT that they are:

   a. ignitable.
   b. toxic.
   c. radioactive.
   d. corrosive.

13. The spaceman economy as described by Boulding would best be attributed to the _____, ______ philosophies.

    a. ecological, pessimistic
    b. aesthetic, pessimistic
    c. utilitarian, optimistic
    d. exploitative, optimistic

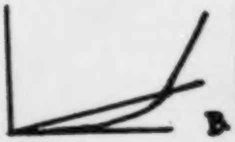
14. All of the following are true about the task force appointed regarding acid rain except:

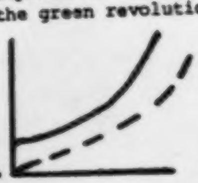
    a. it is a temporary unit
    b. its main purpose is fact finding and research
    c. it will be dissolved when its task is completed
    d. it can make no recommendations to the legislature

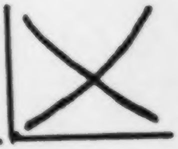
15. All of the following, when graphed, would produce a J-curve EXCEPT:

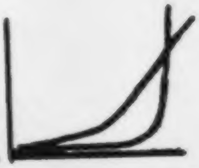
    a. human population through history
    b. amount of pollution in the environment
    c. availability of fossil fuels
    d. demand for fossil fuels since 1920

16. Which graph best depicts the relationship between population and food production since the green revolution?


A.


B.


C.


D.

17. According to Robert Mathus, the solution to the predicted world food shortage was:
    a. the Industrial Revolution
    b. to increase the amount of cropland
    c. enforced population control
    d. environmental resistance

18. The Green Revolution is no longer considered the bright promise to world hunger because it is subject to the:
    a. Tragedy of the Commons
    b. Law of Diminishing Returns
    c. First Law of Thermodynamics
    d. Law of Limiting Factors

19. The biome with the greatest number of species of organisms is the:
    a. deciduous forest
    b. boreal forest
    c. grassland
    d. tropical rain forest

20. The most stratified biome is the:
    a. deciduous forest
    b. boreal forest
    c. grassland
    d. tropical rain forest

21. Forests are an example of a/an ______ resource.
    a. inexhaustible
    b. renewable
    c. nonrenewable
    d. recyclable

22. The best way to increase a wildlife population over the long term is to:
U, a. eliminate density-independent limiting factors
We b. ban sport and commercial hunting
    c. increase environmental resistance
    [✓ d.] create suitable habitats

23. Which energy resource does not belong with the other three?
    [✓ a.] nuclear fission
U, b. hydroelectric
En c. tidal
    d. wind

24. Which of these variables that control the population size of a wildlife species does not belong with the other three?
U, a. competition
We b. predation
    c. disease
    [✓ d.] weather

25. Perhaps the most difficult waste to dispose of is ______ because it resists bacterial breakdown.
    a. aluminum
    b. paper
    c. steel
    d. plastic

26. The largest component of municipal refuse is:
    a. cans
    b. boxes
    c. paper
    d. plastics

27. The law that gave regulatory power to the EPA's solid-waste-management program was the:
    a. Superfund
    b. Resource Conservation & Recovery Act
    c. National Environmental Policy Act
    d. Solid Recovery Act

28. Proper range management, as described in Owen, exhibits which philosophy?
    a. exploitative
    b. aesthetic
    c. ecological
    d. utilitarian

29. Dead plant material that accumulates on the surface of rangeland is called:
    a. alluvium
    b. mulch
    c. mollisol
    d. compost

30. The "Hunger Belt" is considered to be in:
    a. Asia
    b. the tropics
    c. South America
    d. Africa

31. "Cradle to Grave" means/is:
    a. handling of hazardous waste from production to disposal
    b. cancer-causing agents are everywhere in the environment
    c. a program developed by EPA to encourage recycling
    d. identifying the routing and destination of hazardous waste

32. The right to glean a field after harvest refers to the common law of:
    a. estover
    b. pasturage
    c. piscary
    d. shack

33. Land Grant Colleges in the U.S. had their beginnings with the passage of:
    a. The Mitchell Bill
    b. The Pitman-Robertson Act
    c. The Morrill Act
    d. The Hatch Act

34. Maslow's hierarchy, cited by Dr. Roth, states that the most basic human needs are those for:
    a. friendship
    b. love
    c. safety
    d. self-esteem

35. Which state is a major hardwood producer?
    a. Georgia
    b. Maine
    c. Washington
    d. West Virginia

36. From an economic viewpoint, all of the following would result from failing to reduce industrial discharges to a heavily-polluted stream except:
    U, a. avoidance costs
    Ec b. benefits
    c. opportunity costs
    [✓ d.] transaction costs

37. Which energy resource does not belong with the other three?
    M, a. biomass
    b. coal
    En c. wood
    [✓ d.] uranium

M, Ec

38. Which statement about the terms tradeoff tables and political process is accurate?
    a. The political process should not be involved when evaluating alternatives depicted in tradeoff tables.
    b. The monetary effects displayed in a tradeoff table should be determined through the political process.
    c. Nonmonetary benefits and costs on a tradeoff table should not be evaluated through the political process.
    [✓ d.] The political process should be used to weigh alternatives presented in tradeoff tables.

39. Oceans cover how much of the earth's surface?
    a. 60%
    b. 70%
    c. 80%
    d. 90%

40. One who transmits resource information through the mass media is most appropriately called an environmental:
    a. educator
    b. communicator
    c. interpreter
    d. mediator

41. Gifford Pinchot is connected with which major philosophy?
    a. Aesthetic
    b. Ecological
    c. Exploitative
    d. Utilitarian

42. The right of the public sector to take private land for public use with just compensation is an example of the power of:
    a. Eminent Domain
    b. Escheat
    c. Police
    d. Taxation

43. A short-term committee set up by the executive branch to collect facts on a specific problem is a/an:
    a. Agency
    b. Board
    c. Commission
    d. Task Force

44. The normal, realistic flow of information resulting in natural resource policy-making is:
    a. administrators - representatives - public - legislature
    b. legislature - public - representatives - administrators
    c. administrators - legislature - representatives - public
    d. public - representatives - legislature - administrators

45. Thomas Malthus, an eighteenth century economist, predicted that:
    a. population and food production would increase at the same rate
    b. technology would allow food production to increase faster than population
    c. food production could not increase due to the Law of Diminishing Returns
    d. population would increase faster than food production

46. The UN recommends what minimum daily caloric intake for a person doing active work?
    a. 1500
    b. 2200
    c. 2900
    d. 3600

Questions 47 through 49 pertain to the following statement:

A tradeoff table depicts the benefits and costs of a project and shows how these benefits and costs affect different groups of people.

47. The social goal of ______ involves maximizing a project's benefits while minimizing that project's costs.
    M, a. development
    Ec b. equity
    c. abatement
    [✓ d.] efficiency

48. The tradeoff table for a given state-level project may show that local residents receive the most benefits while taxpayers living at the other M, end of the state receive the fewest benefits. This unequal distribution Ec is a question of ______.
    a. development
    [✓ b.] equity
    c. abatement
    d. efficiency

49. In constructing and interpreting a tradeoff table, it is the economist's job to:
    [✓ a.] mathematically calculate a project's monetary effects
    b. determine the best distribution of a project's benefits and costs
    U, c. determine which of several alternate project plans should be adopted
    Ec d. mathematically summarize a project's nonmonetary effects

50. The Tragedy of the Commons is that:
    a. there is no such thing as a free lunch
    b. there is no incentive to conserve a resource that is free to all
    c. there is one common factor that generally limits the size of a population
    d. the amount of resources available to us is steadily decreasing

51. The Executive, Judicial and Legislative branches of government are provided for in:
    a. The Bill of Rights
    b. The Articles of Confederation
    c. The Constitution
    d. The Declaration of Independence

52. According to Owen, the best solution for solving the world food shortage is to:
    a. reduce the birth rate
    b. harvest food from the oceans
    c. cultivate more land
    d. send food and aid to poorer countries

53. High levels of lead in the body adversely affect the:
    a. brain
    b. blood, kidneys and nervous tissues
    c. lungs and respiratory system
    d. cell nucleus and genes

54. The greatest source of air pollution in the U.S. is:
    a. forest fires
    b. industrial processes
    c. fuel combustion in stationary sources
    d. transportation

55. The "greenhouse effect" refers to:
    a. carbon dioxide molecules trapping heat in the atmosphere.
    b. vegetation important as wildlife habitats being raised in greenhouses and transplanted to the wild.
    c. crop improvement as a part of the Green Revolution.
    d. heat lost at each step of the food chain warming the atmosphere.

56. According to Owen, the most extensively used disposal method today is:
    a. sanitary landfill
    b. incineration
    c. composting
    d. surface dumping

57. Which area would you expect to have the most precipitation?
    a. New York City
    b. suburbs around NYC
    c. farm areas west of NYC
    d. the ocean east of NYC

58. According to Prof. Cowen, the base unit for any management activity is the:
    a. habitat
    b. community
    c. ecosystem
    d. niche

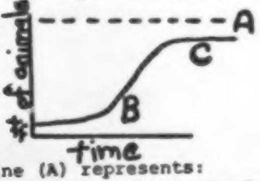
59. Density dependent limiting factors include all of the following except:
    a. shock disease
    b. competition for food
    c. predation by other species
    d. drought

60. Numerically, the most abundant level of a food chain is the:
    a. producers
    b. primary consumers
    c. secondary consumers
    d. decomposers

61. According to Dr. Townsend, the areas of greatest diversity of wildlife population will be:
    a. tropical rain forest
    b. climax forests
    c. clearcuts
    d. ecotones

62. The tendency of a substance to remain in the fatty tissue of an organism after it is eaten is referred to as:
    a. acute toxicity
    b. bioaccumulation
    c. carcinogen
    d. thermodynamics

Questions 63 through 66 refer to the graph below, which shows the growth of a group of animals of one species living in a given area:



63. The dashed line (A) represents:
    a. the average number of animals found in the area at any one time
A, b. the time required for the number of animals to reach the maximum level
We [✓ c.] the maximum number of animals that can live in the area over the long term
    d. the maximum growth rate of the animal group living in the area

64. At point "B" on the curve, growth in numbers was rapid. This is due primarily to the influence of:
M, a. lack of heavy predation upon the species
We b. habitat changes during succession
    [✓ c.] the biotic potential of the species
    d. density-dependent limiting factors

65. At point "C", the curve has nearly leveled off. The main cause of this flattening is the influence of:
M, a. sustained yield
We [✓ b.] environmental resistance
    c. overproduction
    d. irruption

66. Suppose the growth curve crossed the dashed line (A) and remained above that line for several years. In most cases, what would eventually happen?
U, [✓ a.] The carrying capacity would be decreased.
We b. The carrying capacity would no longer influence the number of animals
    c. The carrying capacity would be unaffected
    d. The carrying capacity would be increased

67. The process of decomposition is the reverse of:
    a. bioaccumulation
    b. manipulation
    c. biological succession
    d. photosynthesis

68. The time when food and cover are especially limiting to wildlife is called the:
    a. pinch period
    b. biological low
    c. minimal growth phase
    d. breeding season

69. The major problem with placement of new hazardous waste disposal sites is that they are not:
    a. socioculturally accepted
    b. biophysically safe
    c. economically feasible
    d. legal

70. The coal washing technique:
    a. removes dust from coal so it burns more efficiently
    b. neutralizes the sulfur content by diluting it with water
    c. reduces sulfur and ash contents in coal by 20-50%
    d. removes carbon from coal to prevent CO pollution of the air.

71. All of the following are characteristics of Boulding's cowboy economics EXCEPT:
    a. rapid resource depletion
    b. high durability of goods produced
    c. rapid accumulation of wastes
    d. huge stock of capital goods produced from resources

72. Individuals may buy land which is part of a conservancy district surrounding a lake. They cannot, however, cut any trees on the property without permission or alter the waterfront. This is an example of ______ ownership.
    a. land tenure
    b. land franchise
    c. less than fee simple
    d. fee simple

73. Which condition, when diagrammed, will not yield a pyramid?
    a. the Second Law of Thermodynamics
    b. the Law of Diminishing Returns
    c. the number of organisms on each level of a food chain
    d. the amount of energy lost at each level of a food chain

74. Which economic term does not belong with the other three?
    a. avoidance
    [✓ b.] development
M, c. opportunity
Et d. transaction

75. Which term means essentially the same as environmental resistance?
    a. adaptation
V, b. biotic potential
We c. abiotic components
    [✓ d.] limiting factors

76. When comparing the advantages and disadvantages of using coal, oil or natural gas as energy resources, which of the following statements is true?
V, a. coal causes the least pollution problems
Ee b. coal is the cheapest to transport
    [✓ c.] coal is the most abundant, on a world scale
    d. coal is the easiest to process for use

77. Which energy resource does not belong with the other three?
[✓ a.] wood
M, b. tar sands
c. natural gas
En d. coal

78. The resource utilized to produce energy in a "breeder" reactor may be classified as ______ because ______.
U, a. renewable ... quantities can be maintained through reproduction,
En growth and management.
b. nonrenewable ... environmental conditions aren't right to produce more.
[✓ c.] inexhaustible ... more is produced than consumed in the process.
d. developable ... it is technologically and economically feasible to use it today.

79. The world's potential cropland makes up about ___ percent of the total world land area.
a. 15
b. 25
c. 35
d. 45

80. Which of the following men would likely agree with the philosophy of the film, "Cry of the Marsh"?
a. Richard Nixon
b. Gifford Pinchot
c. Theodore Roosevelt
d. John Muir

81. According to Mr. Nichols, the cost of solving the acid rain problem will be paid by:
U, a. the Ohio EPA
Ec b. the state of Ohio
c. federal block grants
[✓ d.] utility users

82. The major function(s) of the public sector is/are to:
a. produce a profit
b. regulate, enforce and advise
c. generate products
d. organize task forces and conglomerates

83. A given nation's total demand for energy resources is primarily a result of that nation's _____ and _____.
M, a. population size ... carrying capacity
En b. carrying capacity ... resource supply
c. resource quality ... level of living
[✓ d.] level of living ... population size

84. Availability of an energy resource varies with all of the following except:
M, a. the demand for energy
En b. the type of resource
c. the supply of energy resources
[✓ d.] the accuracy of economic forecasts

85. The U.S. uses about half of the world's resources but only has ___% of the world's population.
    a. 18
    b. 14
    c. 10
    d. 6

86. All of the following processes would tend to promote soil formation except:
    a. decomposition
    b. erosion
    c. succession
    d. weathering

87. According to Professor Touse, the "woodbasket" of the U.S. is the ___ forest.
    a. Northern
    b. Pacific
    c. Central
    d. Southern

88. The immediate environment in which an organism lives (including food, cover, water and breeding sites) is called a(n):
    a. habitat
    b. community
    c. ecosystem
    d. niche

89. The process of change of a simple biological community to a complex community and eventual equilibrium is called:
    a. Law of the Minimum
    b. trophic levels
    c. carrying capacity
    d. biotic succession

90. According to Mr. Nichols, the most promising way to treat high sulfur coal without skyrocketing utility costs is the use of:
    a. scrubbers
    b. froth floatation
    c. a fluidized bed
    d. coal washing

91. If a bill originates in and is passed by a Senate standing committee, where does it go next for consideration?
    a. to a House of Representatives standing committee
    b. to the House
    c. to the full Senate
    d. to the Speaker of the House

92. The power to levy taxes lies in which branch of government?
    a. executive
    b. judicial
    c. legislative
    d. all of these

93. In terms of softwoods, which forest region has the production of goods as a primary management objective?
    a. Pacific Northwest
    b. Rocky Mt.
    c. Central
    d. Southern

94. Worldwatch Institute Director, Lester Brown urges, "...that we move boldly ahead with new programs to restore the productivity of our renewable resources while making the wisest possible use of remaining non-renewables," and calls for revised life-styles and frugality. From the preceeding, Brown's philosophy appears to be:
    a. exploitative ... pessimistic
    b. utilitarian ... optimistic
    c. aesthetic ... optimistic
    d. ecological ... pessimistic

95. "Dear Mr. President: If you've never held a baby white-tailed deer, if you've never seen red fox pups playing, if you're never thrilled at seeing a red-tailed hawk fly free, you can't understand why so many Americans are becoming concerned about our environment and wild creatures."

    This paragraph from a letter to Reagan requesting Secretary Watt's replacement reflects the writer's ______ philosophy.
    a. exploitative
    b. utilitarian
    c. ecological
    d. aesthetic

96. According to Dr. Logan, the most reactive soil particles are:
    a. sand
    b. clay
    c. gravel
    d. silt

97. A biome is defined by its:
    a. climate
    b. latitude and longitude
    c. animal species
    d. vegetation

98. Succession in central Ohio leads to a climax vegetation type called:
    a. associated grassland forest
    b. boreal mixed forest
    c. coniferous hardwood forest
    d. deciduous forest

99. During the Second Conservation Wave, it was realized that effective environmental management could best be handled by:
    a. individual states
    b. local governments
    c. the federal government
    d. special interest groups

100. The enforcement of strip mining regulations by the state government is an example of the public sector's _____ power.
    a. eminent domain
    b. propriety
    c. taxation
    d. police

APPENDIX J

CONCEPT MAPPING ATTITUDE ASSESSMENT

Name ______________________________

Group ______________

Natural Resources 201
Concept Learning Research Program

CONCEPT MAPPING ATTITUDE ASSESSMENT

This questionnaire is intended to find out your opinions about the concept mapping instruction and assignments that were incorporated into Natural Resources 201 this quarter.

For each of the 10 statements below, circle the response that best describes your attitude towards each statement.

SA = Strongly Agree

A = Agree

N = Neutral

D = Disagree

SD = Strongly Disagree

For example:

0. I like butterscotch brownies. SA [✓ A] N D SD

The circled letter "A" indicates that the student agreed with the statement.

- -

1. Concept maps help me learn concepts.	SA	A	N	D	SD
2. Learning how to make a concept map was difficult.	SA	A	N	D	SD
3. Making a concept map is not efficient use of my time.	SA	A	N	D	SD
4. I think I would learn more by making my own concept maps than I would by reading one made by an instructor.	SA	A	N	D	SD
5. I know how to learn concepts meaningfully, instead of simply memorizing them.	SA	A	N	D	SD
6. The concept maps I have made have not been helpful in my studying.	SA	A	N	D	SD
7. Making concept maps is easy.	SA	A	N	D	SD
8. By participating in the concept mapping program, I have a better understanding of how people learn.	SA	A	N	D	SD
9. I do not expect to make any more concept maps.	SA	A	N	D	SD
10. This program taught me nothing useful about how people learn.	SA	A	N	D	SD

(continued on reverse)

Please also comment on the following questions.

1. Should concept mapping lessons and assignments be part of a course such as Natural Resources 201? __________ Why or why not?

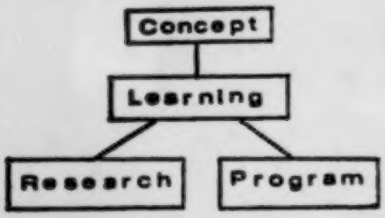
2. Was the concept mapping technique made clear to you by the slide-tape program and manual? __________ In what ways could this instruction be improved?

3. In all honesty, was participating in the concept mapping program worth your time? __________ Why or why not?

4. Do you have any other comments?

If you would like a short summary of the findings of this research project, write your spring quarter address (campus address, if possible) below.

Many thanks for your time and cooperation!
- Woody Bousquet



APPENDIX K

QUESTIONNAIRE
COMPLETED BY PANELISTS WHO
REVIEWED CONCEPT MAPPING MODULES

Reviewer's Name: ______________________________

VALIDATION OF
CONCEPT MAPPING INSTRUCTIONAL STRATEGIES

1. Read the script for Group 1.

2. Use the manual as directed in the script.

3. Answer the following question:

   What features should a concept map have, according to the Group 1 materials?

   Group 1 ____

   ____

   ____

   ____

   ____

4. Read the script for Group 2.

5. Use the manual as directed in the script.

6. Answer the following question:

   What features should a concept map have, according to the Group 2 materials?

   Group 2 ____

   ____

   ____

   ____

7. Read the script for Group 3.

8. Use the manual as directed in the script.

(continued next page)

9. Answer the following question:

What features should a concept map have, according to the Group 3 materials?

Group 3 ____

Thank you for your time and cooperation.

Please return this questionnaire to Woody Bousquet, 246 Lord Hall or 283 Arps Hall, by Wednesday, October 7. Any comments you wish to make on the script or manuals are most welcome.

APPENDIX L

RESULTS OF TESTS FOR TREATMENT GROUP EQUALITY

Table 37

Analysis of Variance Summary Tables for Tests of Treatment Group Equality

ANOVA for Prior Knowledge by Treatment Group

Source	Sum of Squares	DF	Mean Square	F	Signif of F
Treatment Group	4.49	2	2.25	0.20	0.822
Residual	1291.46	113	11.43		
Total	1295.95	115	11.27		

ANOVA for TOLT by Treatment Group

Source	Sum of Squares	DF	Mean Square	F	Signif of F
TOLT	19.83	2	9.91	1.39	0.253
Residual	805.91	113	7.13		
Total	825.74	115	7.18		

ANOVA for Biology Credits by Treatment Group

Source	Sum of Squares	DF	Mean Square	F	Signif of F
Biology Credits	330.24	2	165.12	5.50	0.005
Residual	3392.20	113	30.02		
Total	3722.44	115	32.37		

Table 37 (Continued)

ANOVA for Natural Resources Credits by Treatment Group

Source	Sum of Squares	DF	Mean Square	F	Signif of F
Natural Resources Credits	30.81	2	15.41	0.75	0.476
Residual	2328.35	113	20.61		
Total	2359.16	115	20.51		

ANOVA for Social Sciences Credits by Treatment Group

Source	Sum of Squares	DF	Mean Square	F	Signif of F
Social Sciences Credits	11.96	2	5.98	0.29	0.753
Residual	2370.61	113	20.98		
Total	2382.57	115	20.72		

ANOVA For Other Credits by Treatment Group

Source	Sum of Squares	DF	Mean Square	F	Signif of F
Other Credits	97.15	2	48.58	2.84	0.063
Residual	1934.59	113	17.12		
Total	2031.74	115	17.67		

Table 37 (Continued)

ANOVA for Total Credits by Treatment Group

Source	Sum of Squares	DF	Mean Square	F	Signif of F
Total Credits	1163.15	2	581.58	4.92	0.009
Residual	13362.54	113	118.25		
Total	14525.70	115	126.31		

Table 38

Multiple Regression Summary Tables for Tests of Treatment Group Equality

Dependent Variable: Membership in Group 1

Variable	R Squared	RSQ. Change	Simple R	Beta
Biology Credits	0.07	0.07	-0.27	-0.26
Other Credits	0.07	0.00	-0.09	-0.06

Dependent Variable: Membership in Group 2

Variable	R Squared	RSQ. Change	Simple R	Beta
Total Credits	0.08	0.08	0.28	0.06
Biology Credits	0.09	0.01	0.25	0.20
Other Credits	0.10	0.01	0.22	0.16

Dependent Variable: Membership in Group 3

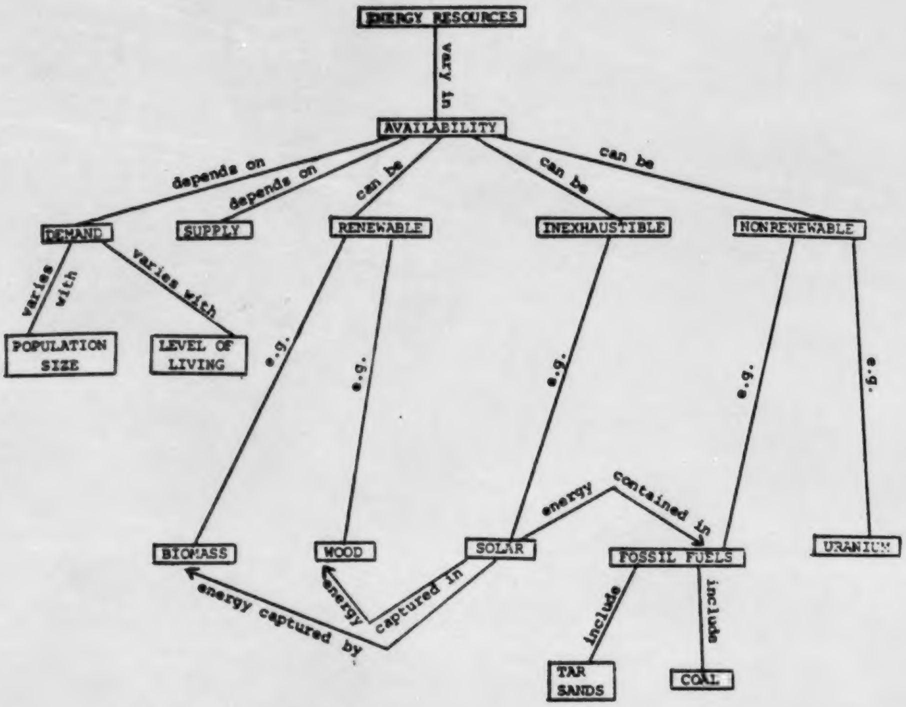
Variable	R Squared	RSQ. Change	Simple R	Beta
Other Credits	0.02	0.02	-0.14	-0.10
Biology Credits	0.02	0.00	0.01	0.06
Total Credits	0.02	0.00	-0.09	-0.07

APPENDIX M

MASTER MAPS FOR THE THREE CONCEPT MAPPING ASSIGNMENTS

MASTER MAP

CONCEPT MAP 1. TREATMENT GROUP 1


ENERGY RESOURCES
vary in
AVAILABILITY
depends on
depends on
can be
can be
can be
DEMAND
SUPPLY
RENEWABLE
INEXHAUSTIBLE
NONRENEWABLE
varies with
varies with
POPULATION SIZE
LEVEL OF LIVING
e.g.
e.g.
e.g.
e.g.
e.g.
energy contained in
BIOMASS
WOOD
SOLAR
FOSSIL FUELS
URANIUM
energy captured by
energy captured in
include
include
TAR SANDS
COAL

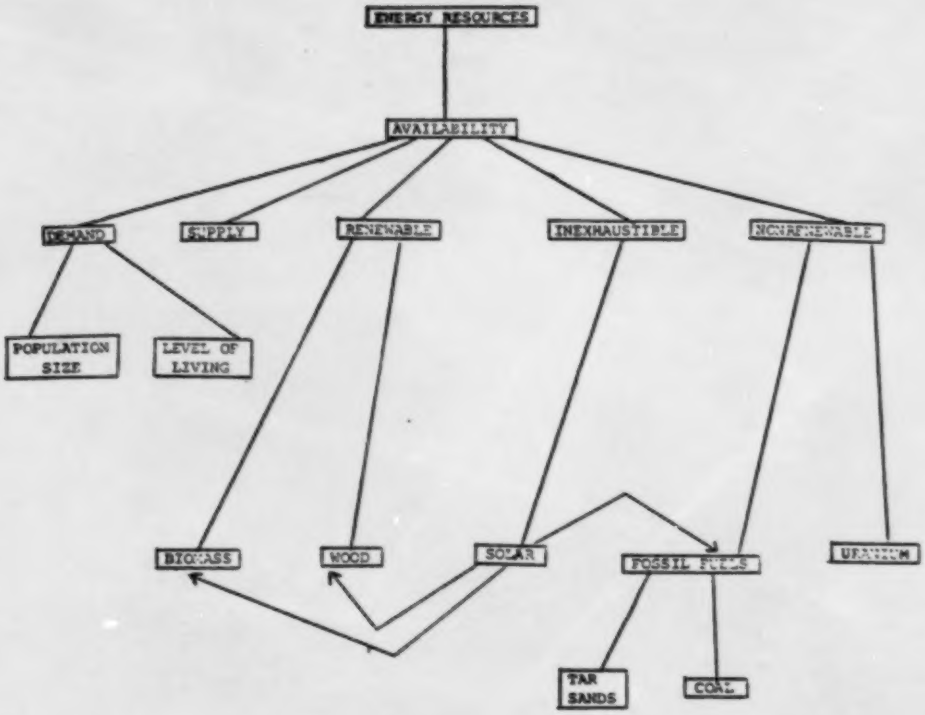
Relationships 18 **points** **Hierarchy** 4

Branching 11 **Cross Links** 6

TOTAL SCORE 41

MASTER MAP

CONCEPT MAP 1, TREATMENT GROUP 2


ENERGY RESOURCES
AVAILABILITY
DEMAND
SUPPLY
RENEWABLE
INEXHAUSTIBLE
NONRENEWABLE
POPULATION SIZE
LEVEL OF LIVING
BIOMASS
WOOD
SOLAR
FOSSIL FUELS
URANIUM
TAR SANDS
COAL

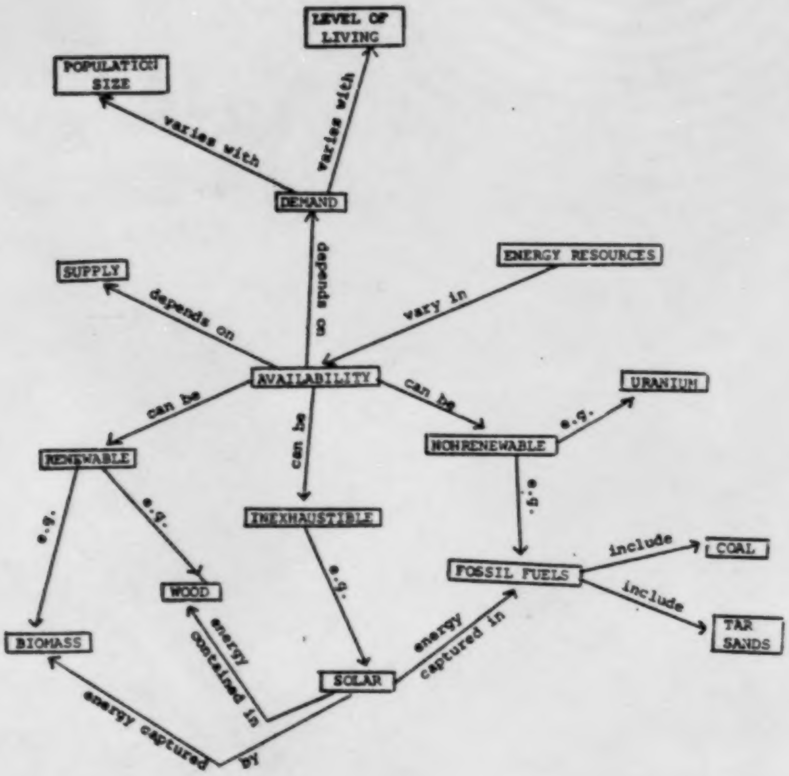
Relationships 18 points   Hierarchy 4

Branching 11   Cross Links 6

TOTAL SCORE 41

MASTER MAP

CONCEPT MAP 1, TREATMENT GROUP 3


LEVEL OF LIVING
POPULATION SIZE
varies with
varies with
DEMAND
depends on
SUPPLY
depends on
ENERGY RESOURCES
vary in
AVAILABILITY
can be
can be
can be
URANIUM
e.g.
RENEWABLE
NONRENEWABLE
INEXHAUSTIBLE
e.g.
e.g.
e.g.
e.g.
include
COAL
FOSSIL FUELS
include
TAR SANDS
WOOD
BIOMASS
energy contained in
SOLAR
energy captured in
energy captured by

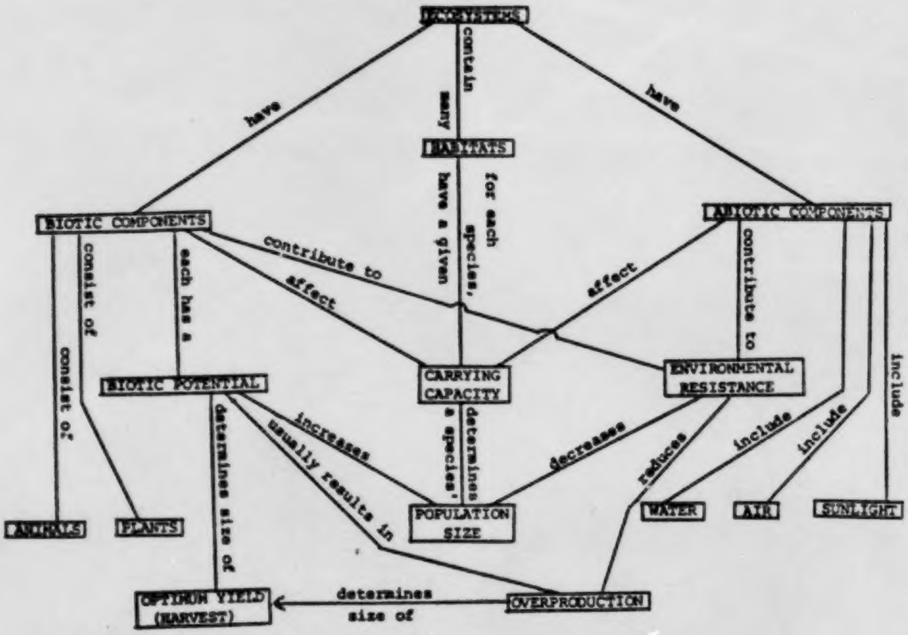
Relationships 18 points   Branching 16

Cross Links 6

TOTAL SCORE 40

MASTER MAP

CONCEPT MAP 2. TREATMENT GROUP 1

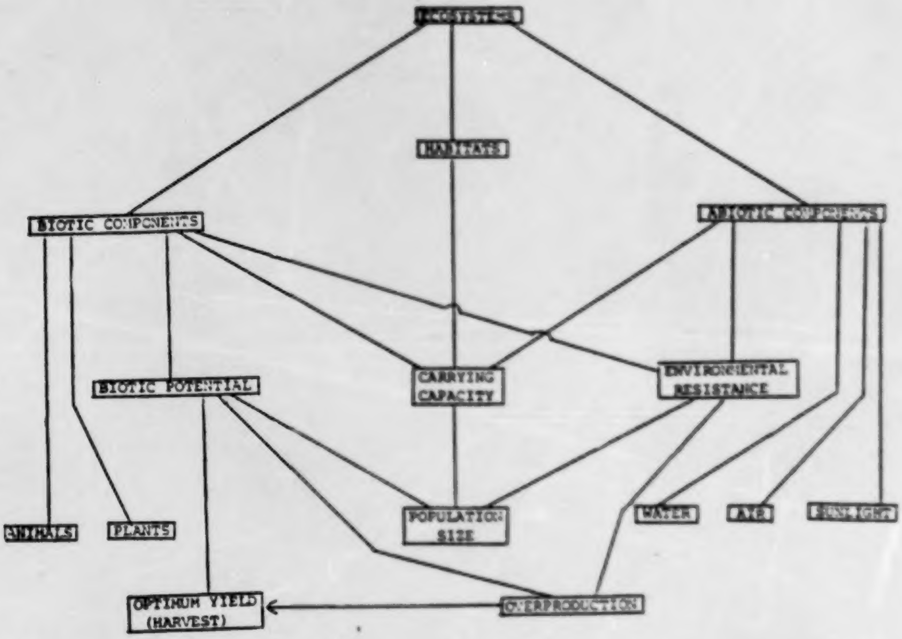

ECOSYSTEMS
have
contain many
have
HABITATS
have a given
for each species,
BIOTIC COMPONENTS
ABIOTIC COMPONENTS
contribute to
affect
affect
consist of
each has a
contribute to
include
consist of
BIOTIC POTENTIAL
CARRYING CAPACITY
ENVIRONMENTAL RESISTANCE
increases
a species'
determines
decreases
reduces
include
include
determines size of
usually results in
ANIMALS
PLANTS
POPULATION SIZE
WATER
AIR
SUNLIGHT
OPTIMUM YIELD (HARVEST)
determines size of
OVERPRODUCTION

Relationships	21 points	Hierarchy	3
Branching	13	Cross Links	14

TOTAL SCORE 51

MASTER MAP

CONCEPT MAP 2, TREATMENT GROUP 2


ECOSYSTEMS
HABITATS
BIOTIC COMPONENTS
ABIOTIC COMPONENTS
BIOTIC POTENTIAL
CARRYING CAPACITY
ENVIRONMENTAL RESISTANCE
ANIMALS
PLANTS
POPULATION SIZE
WATER
AIR
SUNLIGHT
OPTIMUM YIELD (HARVEST)
OVERPRODUCTION

Relationships 21 points

Hierarchy 5

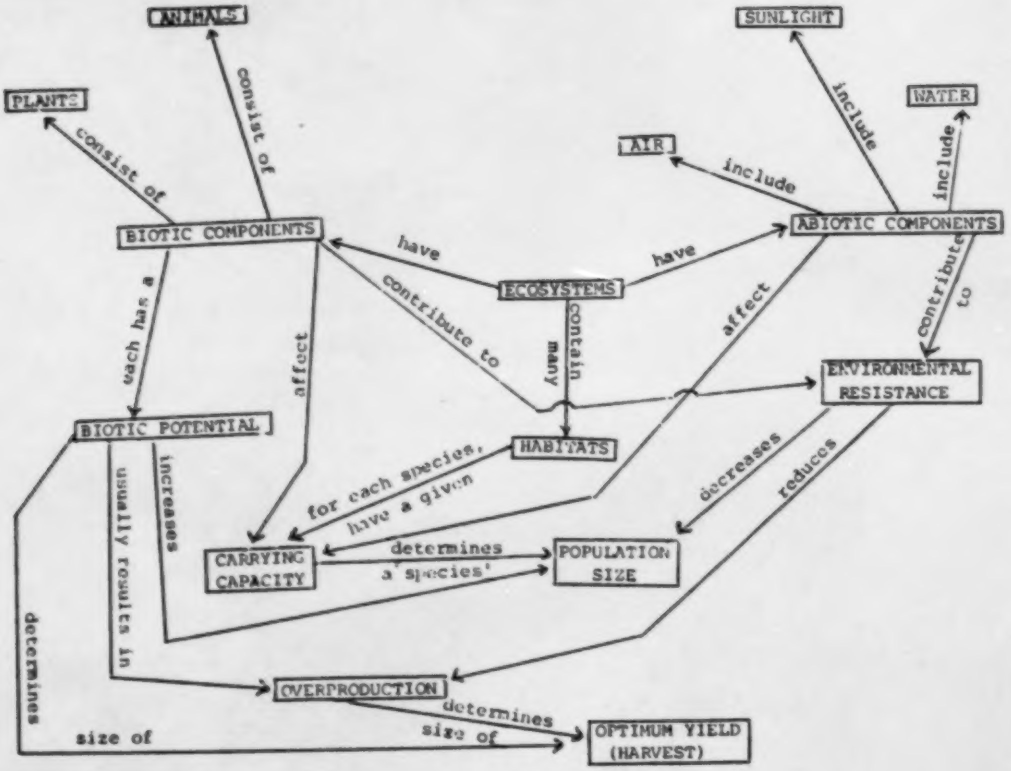
Branching 11

Cross Links 14

TOTAL SCORE 51

MASTER MAP

CONCEPT MAP 2, TREATMENT GROUP 3


ANIMALS
PLANTS
SUNLIGHT
WATER
AIR
consist of
consist of
include
include
include
BIOTIC COMPONENTS
ABIOTIC COMPONENTS
have
have
ECOSYSTEMS
each has a
contribute to
contain many
affect
affect
contribute to
ENVIRONMENTAL RESISTANCE
BIOTIC POTENTIAL
HABITATS
for each species, have a given
increases
usually results in
decreases
reduces
CARRYING CAPACITY
determines a'species'
POPULATION SIZE
determines size of
OVERPRODUCTION
determines size of
OPTIMUM YIELD (HARVEST)

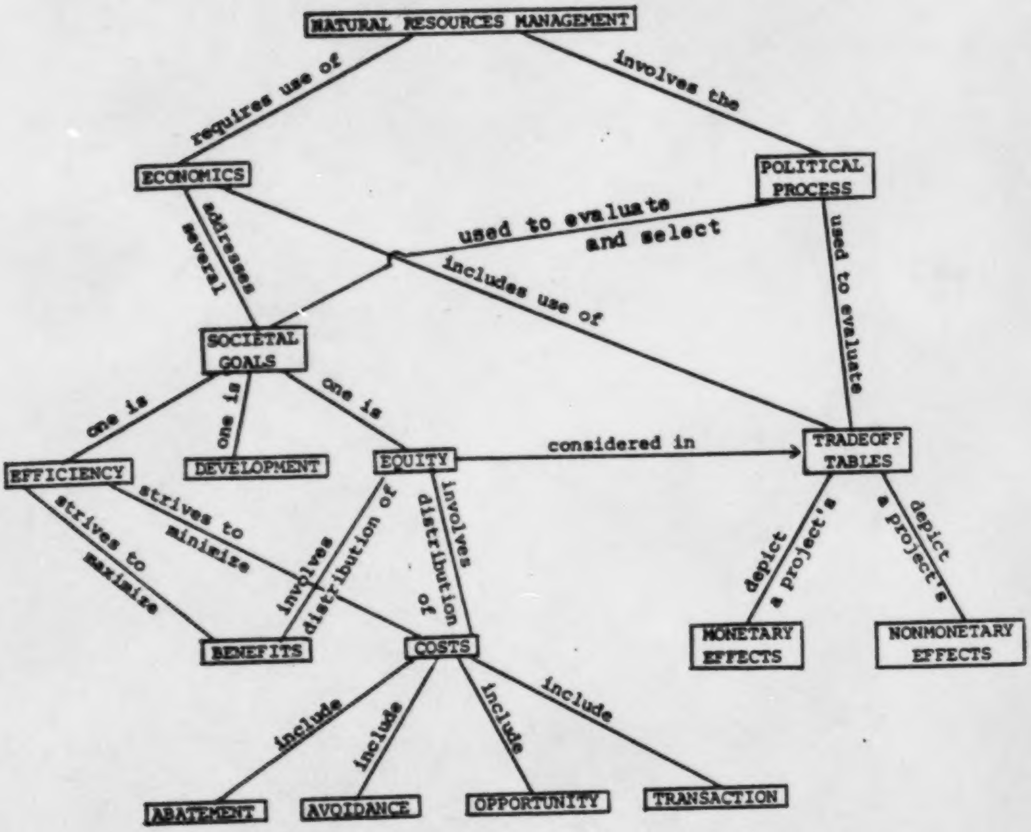
Relationships 21 points **Branching** 13

Cross Links 14

TOTAL SCORE 48

MASTER MAP

CONCEPT MAP 3, TREATMENT GROUP 1


NATURAL RESOURCES MANAGEMENT
requires use of
involves the
ECONOMICS
POLITICAL PROCESS
addresses several
used to evaluate and select
includes use of
used to evaluate
SOCIETAL GOALS
one is
one is
one is
EFFICIENCY
DEVELOPMENT
EQUITY
considered in
TRADEOFF TABLES
strives to maximize
strives to minimize
involves distribution of
involves distribution of
depict a project's
depict a project's
BENEFITS
COSTS
MONETARY EFFECTS
NONMONETARY EFFECTS
include
include
include
include
ABATEMENT
AVOIDANCE
OPPORTUNITY
TRANSACTION

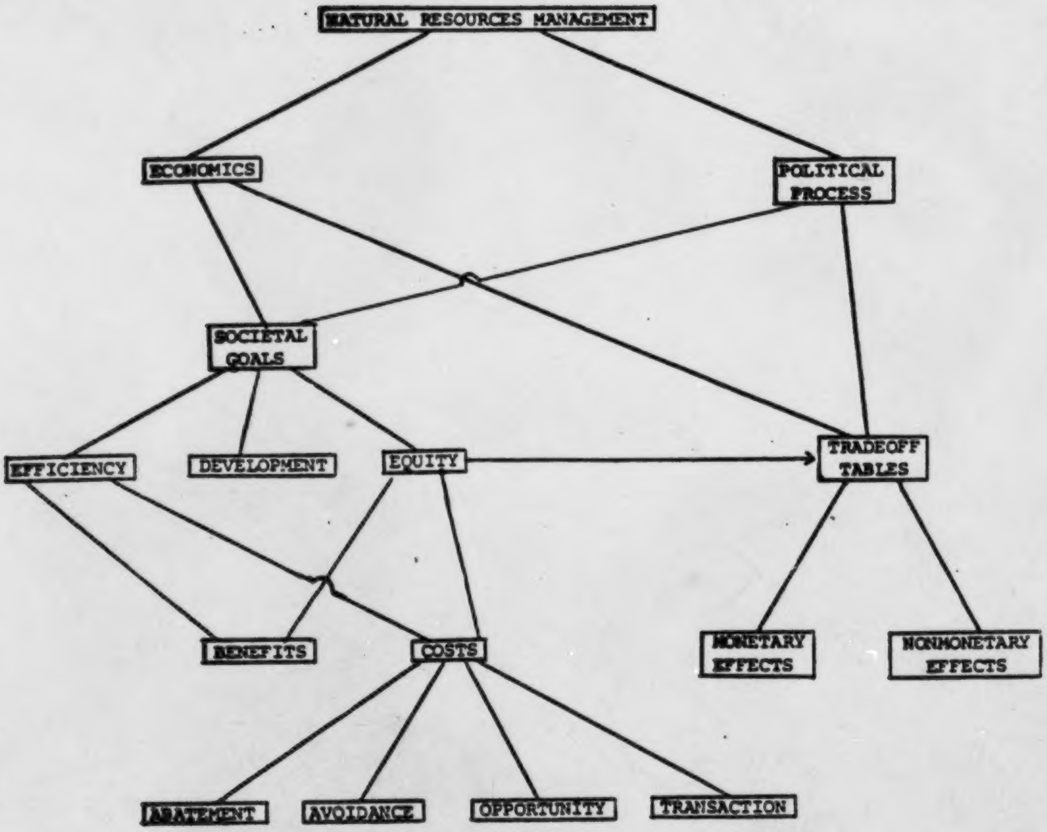
Relationships 20 points **Hierarchy** 5

Branching 22 **Cross Links** 10

TOTAL SCORE 57

MASTER MAP

CONCEPT MAP 3, TREATMENT GROUP 2


NATURAL RESOURCES MANAGEMENT
ECONOMICS
POLITICAL PROCESS
SOCIETAL GOALS
EFFICIENCY
DEVELOPMENT
EQUITY
TRADEOFF TABLES
BENEFITS
COSTS
MONETARY EFFECTS
NONMONETARY EFFECTS
ABATEMENT
AVOIDANCE
OPPORTUNITY
TRANSACTION

Relationships 20 points

Branching 22

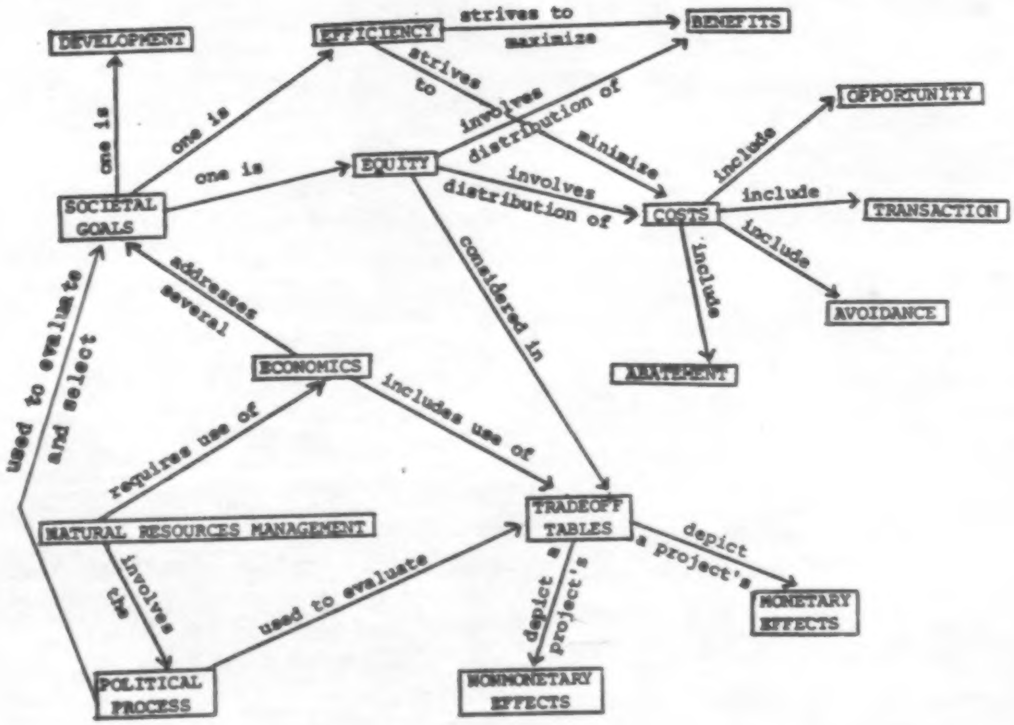
Hierarchy 5

Cross Links 10

TOTAL SCORE 57

MASTER MAP

CONCEPT MAP 3, TREATMENT GROUP 3


DEVELOPMENT
EFFICIENCY
strives to maximize
BENEFITS
strives to minimize
one is
one is
one is
SOCIETAL GOALS
EQUITY
involves distribution of
involves distribution of
OPPORTUNITY
include
include
TRANSACTION
COSTS
include
include
AVOIDANCE
ABATEMENT
considered in
addresses several
ECONOMICS
used to evaluate and select
requires use of
includes use of
NATURAL RESOURCES MANAGEMENT
TRADEOFF TABLES
depict a project's
depict a project's
MONETARY EFFECTS
NONMONETARY EFFECTS
involves the
used to evaluate
POLITICAL PROCESS

Relationships 20 points **Branching** 22

Cross Links 10

TOTAL SCORE 52